This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

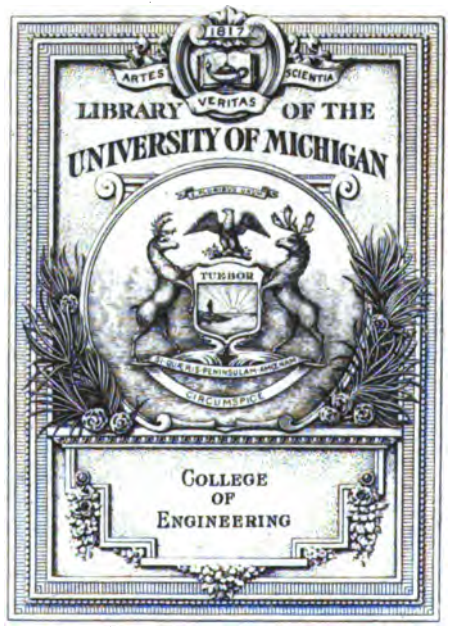
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`


1817
ARTES
SCIENTIA
VERITAS
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
TUEBOR
COLLEGE
OF
ENGINEERING

ENGINEERING
LIBRARY
TA
616
.D19
1907

TECHNICAL DRAWING SERIES

A TEXT-BOOK

OF

TOPOGRAPHICAL DRAWING

BY

FRANK T. DANIELS, A.M.B.

AUTHOR OF "A TEXT-BOOK OF FREE-HAND LETTERING"

D. C. HEATH & CO., PUBLISHERS

BOSTON NEW YORK CHICAGO

COPYRIGHT, 1907,
BY FRANK T. DANIELS.

118

Engin.
Wash
6-27-21
24218

PREFACE

THIS book is offered to supply the need which several years' experience in giving instruction to students of engineering led the author to perceive.

It presents the technical details of topographical drawing, together with problems involving the design of earthwork structures, and calculations relating to them.

A leading feature of the other books of the "Technical Drawing Series" has been followed; namely, the presentation of exercises and problems each with a definite lay-out, thus adapting the book for use in large classes.

It is assumed that the student will have acquired some proficiency in mechanical drawing before taking up the work here presented, therefore the descriptions of instruments and explanations of processes do not include those which are ordinarily given in a good course in mechanical drawing. Indeed, the aim throughout the preparation of the book has been to avoid duplicating anything that the student may well learn from some other source; also to gather into form immediately available to a draftsman those things which his other books cannot consistently include, or which are not presented in a sufficiently concrete form to be of the greatest use.

BOSTON, MASSACHUSETTS,
December, 1906.

TABLE OF CONTENTS

CHAPTER I

INTRODUCTORY

ART.		PAGE
1.	Definition	1
2.	Implements and Materials	1
3.	Beam Compasses	2
4.	The Contour or Curve Pen	3
5.	The Railroad Pen	3
6.	Proportional Dividers	3
7.	Scales	4
8.	Curves	6
9.	Protractors	6
10.	Section Liner	8
11.	The Planimeter	9
12.	The Pantograph	10
13.	The Copying Glass	11
14.	The Straightedge	12
15.	Needle Point or Pricker	12
16.	Paper Weights	13
17.	Paper	13
18.	Pens and Holder	16
19.	Brushes	17
20.	Water Glass	17
21.	Color Saucers	17
22.	Colors	18
23.	Colored Pencils	18

CHAPTER II

PRELIMINARY PROBLEMS AND OPERATIONS

24.	To divide a Given Distance into Equal Parts	19
25.	To divide an Arc into Equal Parts	19
26.	To find Points on an Arc of Large Radius	20
27.	Multipliers for Planimeter Measurements	21
28.	Rating the Planimeter	21
29.	Stretching Paper	23
30.	Mounting Paper on Cloth	25
31.	Splicing Paper	26
32.	Patching Tracing Cloth	27

CHAPTER III

PLOTTING

ART.		PAGE
33.	The General Problem	28
34.	Plotting a Triangulation	28
35.	Plotting Progressive Angles	29
36.	Protracting an Angle	29
37.	To plot an Angle by its Tangent	30
38.	To plot an Angle by the Chord of its Subtended Arc	30
39.	Defect of Plotting Progressive Angles	30
40.	Deflection Angle	31
41.	Bearings	32
42.	Azimuth	33
43.	Plotting by Total Latitudes and Longitudes	33
44.	Surveys based on a System of Coördinates	35
45.	Plotting Surface Markings	37
46.	Problems	39

CHAPTER IV

TOPOGRAPHICAL DRAWING IN INK

47.	Topographical Symbols in General	42
48.	The Sizes and Distribution of Symbols	43
49.	Grass Land	44
50.	Cleared Land	45
51.	Cultivated Land	45
52.	Sand, Gravel, and Mud	46
53.	Trees	47
54.	Foliage in Mass	47
55.	Fresh Marsh	48
56.	Salt Marsh	49
57.	Water	49
58.	Roads and Streets	51
59.	Railways	51
60.	Embankments and Cuts	51
61.	Ledge	52
62.	Fence, Wall, and Hedge	52
63.	Buildings	52
64.	Exercises	57

CHAPTER V

TOPOGRAPHICAL DRAWING IN COLORS

65.	Preparation of the Color	58
66.	The Nature of a Tint	58
67.	Applying the Color	59
68.	Inking	61
69.	Making Corrections	62
70.	Laying a Graded Tint	62

ART.		PAGE
71.	Blending	63
72.	Mottling	64
73.	Dragging	65
74.	Matching a Color	66
75.	Combinations of Colors	67
76.	Special Combinations of Colors	68
77.	Topographical Drawing in Colors	69
78.	Grass Land	70
79.	Cleared Land	70
80.	Cultivated Land	70
81.	Sand and Gravel	70
82.	Mud	70
83.	Individual Trees	70
84.	Trees in Mass	73
85.	Fresh Marsh	73
86.	Salt Marsh	74
87.	Water	74
88.	Streets and Roads	77
89.	Railways	77
90.	Embankments and Cuts	77
91.	Ledge, or Rocky Surface	77
92.	Fences, Walls, and Hedges	77
93.	Buildings	78
94.	Use of Colored Pencils	78
95.	Use of the Stump	79
96.	Colored Pencils with Tracing Paper and Tracing Cloth	79
97.	Colors in relation to Blueprinting	80
98.	Colored Whiteprints	80
99.	Exercises in Water Coloring; General Directions	80
100.	Exercise in Flat Tints	81
101.	Exercise in Graded Tints and in Mottling	81
102.	Exercise in Conventional Tints and Symbols	81
103.	Exercise in Conventional Tints and Symbols (*continued*)	82
104.	Application of Conventional Tints and Symbols	83

CHAPTER VI

SURFACE FORMS AND EARTHWORK

105.	Representation of Surface Forms	84
106.	Representation by Recorded Elevations	85
107.	Representation by Profile	85
108.	Cross-sections	87
109.	Representation by Contour Lines	87
110.	Interpolation of Contours	89
111.	Interpolation from Corners of Rectangles	90
112.	Interpolation on the Assumption of Straight Grades	92
113.	Summary of Principles regarding Contours	93
114.	Determination of Slopes and their Intersections	94
115.	Earthwork, General Statement	97
116.	Method by Four-sided Prisms	97
117.	Method by Three-sided Prisms	98
118.	The Prismoidal Method	99
119.	Consecutive Prismoids	100
120.	Application of Prismoidal Method to Grading	101

ART.		PAGE
121.	Methods approximating the Prismoidal Method	101
122.	Volume from a Contour Map	102
123.	Treatment of the Plan	106
124.	Balancing Cuts and Fills	107
125.	Problems	108

CHAPTER VII

CONVENTIONAL TREATMENT FOR SURFACES AND SECTIONS

126.	Reasons for Treatment	115
127.	Materials in Elevation	115
128.	Materials in Section	120
129.	Materials in Section (*continued*)	124
130.	Geological Profiles and Sections	128
131.	Borings	133
132.	Illustration of Cross-sectioning and Rendering	133

CHAPTER VIII

COPYING, REDUCTION, AND ENLARGEMENT OF PLANS

133.	Copying by Blueprinting	134
134.	The Sensitizing Solution	135
135.	Making Corrections on Blueprints	136
136.	The Printing Value of Colors	136
137.	Printing from a Thick Drawing	137
138.	Copying by Means of Vandyke Negatives	137
139.	Making Corrections on Vandyke Negatives	138
140.	Special Uses of Vandyke Negatives	138
141.	Use of the Copying Glass	139
142.	Copying by Pricking	139
143.	Copying with Transfer Paper	139
144.	Copying, Enlarging, and Reducing by the Pantograph	140
145.	Reducing and Enlarging by Proportional Squares	140
146.	Photography, Lithography, and Photo-engraving	142
147.	Color Work by Photo-engraved Plates	143

A TEXT-BOOK OF TOPOGRAPHICAL DRAWING

TEXT-BOOK OF TOPOGRAPHICAL DRAWING

CHAPTER I

INTRODUCTORY

1. Definition. Topographical Drawing is the art of representing in a graphical manner, a limited portion of the earth's surface, including not only the natural features, such as trees, streams, and marshes, but also such artificial features as roads and buildings.

These objects are shown in their true geographical relations, and, although the representation is made on a single flat sheet of paper, the surface configuration is generally indicated. Sometimes this is done in a relative way only, showing where elevations and depressions occur, and sometimes sufficient information is given so that the exact heights and depths can be determined from the drawing.

The geographical positions of objects are fixed in accordance with some suitable predetermined scale, so that the drawing is an exact representation of the portion of the earth's surface shown, including the artificial features referred to. Horizontal distances can therefore be measured on the finished drawing by using the scale that was employed in making it.

2. Implements and Materials. It is assumed that the student is familiar with the instruments, materials, and operations of ordinary mechanical drawing. Hence only such of these as are used particularly in topographical drawing will be described.

3. Beam Compasses. This instrument is used for drawing arcs of greater radius than is possible with the ordinary compasses and extension bar, and even for arcs which are within the range of the latter, when very exact work is necessary.

The instrument consists of two blocks of German silver, Fig. 1, each having a socket at its lower edge. Into one of these can be fitted a leg carrying a needle point for the center. The leg in the other block carries either a pen or pencil point. The blocks are fastened to a long "beam" of hard wood by means of the screws A, A. The leg carrying the needle point is pivoted at B, and its motion around the pivot is controlled by the spring S, and the thumb nut N. The required radius is first obtained approximately by sliding the blocks along the beam. After having clamped them, the adjustment to the exact radius is secured by turning the nut. There is shown also an end view of a block and the beam. It will be noted that the screws A, A do not bear directly upon the beam, but upon intermediate strips of metal. These strips do not extend to the bottom of the slots in the blocks, and the spaces thus left are occupied by a slight projection on the lower edge of the beam, the purpose of which is to prevent the blocks from dropping off when the thumb nut is loosened. It is convenient to have three or four beams varying from one to six or eight feet in length.

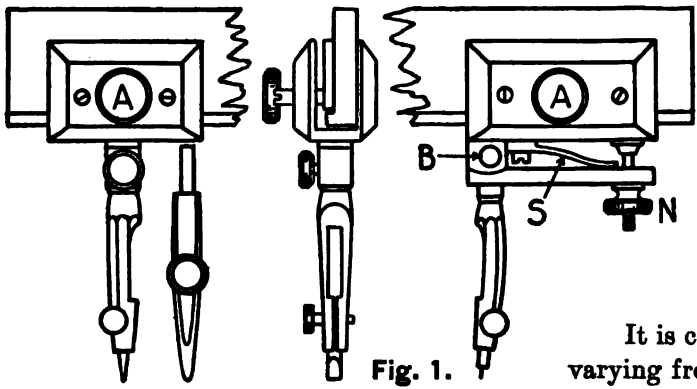


Fig. 1.

4. The Contour or Curve Pen. This is like a right-line pen except that the blades are curved, as shown in Fig. 2, and the shank passes entirely through the handle, terminating in a nut at the top. When this nut is loose, the pen swivels freely in the handle. The purpose of the pen is for drawing free-hand lines, such as contour lines (Art. 109). In use the instrument is held vertically. Because of their curved form the blades trail along after the handle, thus causing them to be always in a position to yield a line of uniform thickness. To obtain the same result with the right-line pen a constant turning of the wrist is necessary.

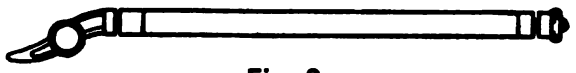


Fig. 2.

5. The Railroad Pen. This, as shown in Fig. 3, is simply a double-pointed, right-line pen. Its use saves much time when many parallel lines are to be drawn, as those showing the rails of a railroad track, or the side lines of roads. It is also useful for drawing very wide lines. For this purpose the points are brought near together, the blades in each point are opened wide, and ink is placed not only between the blades, but also between the points. With the proper adjustment of distances between points and blades a line fully one eighth of an inch wide can be drawn with fairly square ends.

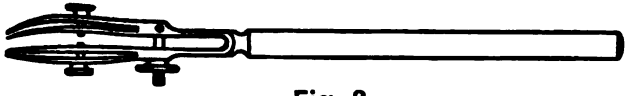


Fig. 3.

6. Proportional Dividers. As shown by Fig. 4 this form of dividers has points at each end. The pivot can be shifted along

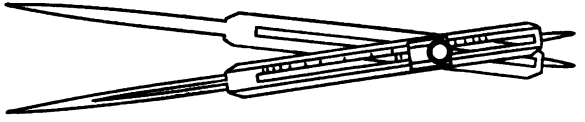


Fig. 4.

the slots in the legs so that any desired ratio of opening between the points at the opposite ends of the instrument can be secured.

The principal use of this instrument is in reducing and enlarging maps, Sect. 145.

7. Scales. A map is necessarily very much smaller than the portion of the earth's surface which it represents, and the scales used for architectural and mechanical drawing are, therefore, not suitable for topographical drawing.

The scales generally used in topography are called "scales of equal parts," or "chain scales." For instance, a scale of 1 inch = 40 feet, means that an inch on the scale is taken to represent forty feet on the ground. The inch is then divided into forty equal parts, each of which represents one foot on the ground. But since the lines to be drawn may represent many times forty feet, the whole edge of the scale (from one to two feet long) is divided into fortieths of an inch, and each twentieth division is numbered. Thus the scale above described (often called simply "a forty scale") if made twelve inches long will contain 480 divisions, the last one being numbered simply 48, the final 0 being understood at each numbered division. A drawing made to this scale will bear a ratio in its linear dimensions of $\frac{1}{12 \times 40} = \frac{1}{480}$ to the lines upon the ground which it represents.

The scales usually employed in topographical drawing have the inch divided into 10, 20, 30, 40, 50, 60, 80, and 100 parts. Drawings are often made to a scale of 1 in. = 300 ft., but the scale used is the "thirty scale," the intervals on the scale being mentally multiplied by ten.

Scales are made of Bristol board, boxwood, and steel. The first are not accurate enough

for fine work. Those made of boxwood are most satisfactory, especially if the edges are finished with strips of white celluloid on which the divisions are marked in black.

Fig. 5 shows the triangular and flat forms of boxwood scales. The former contains six scales, the latter contains two.

The chief objection to the triangular form is that it must rest on the divided edges and the divisions get worn away. Another objection is that the wrong scale is more liable to be used than is the case with the flat form. For instance the 30 and 40 scales of the triangular form may easily be mistaken for one another, while the two scales on the flat form are very different, such as 10 and 40, so that they are not as liable to be confounded.

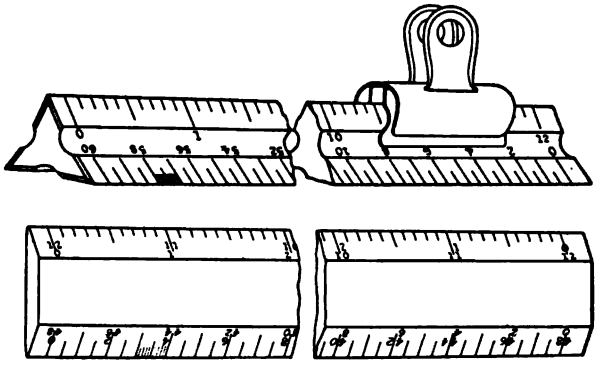


Fig. 5.

This last objection to the triangular form may be overcome by the use of a "scale guard." This is a metal clip which is placed on the top angle of the scale. It should be placed at one end, as the right, then the draftsman knows that when it is in this position before him, the proper scale for use is at the edge remote from the body.

Scale guards made for this purpose alone are sold by dealers, but the form of paper clip shown in Fig. 5 is quite as satisfactory and much cheaper.

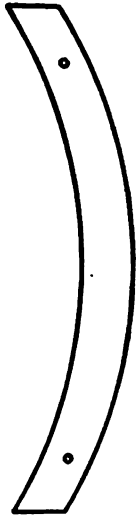


Fig. 6. Fig. 7.

8. Curves. Beside the "French," or "irregular," curves which form a part of every draftsman's outfit, a few ship curves and a set of railroad curves are usually found in a drafting office.

Ship Curves are made of pearwood, hard rubber, or celluloid. Fig. 6 shows a typical form. They are about 24 inches long, and contain long, sweeping curves of constantly varying radius.

Railroad Curves, Fig. 7, are made of cardboard, pearwood, hard rubber, celluloid, or zinc. A set contains from 10 to 100 pieces. The set suitable for most purposes contains 44 pieces, which vary in radius from 3 to 200 inches, and in length from about 5 to 18 inches. Both curved edges of a piece are cut to the same radius, and each piece is stamped with a number expressing its radius in inches.

9. Protractors. The protractor is an instrument for laying off angles or for measuring angles already laid down on the drawing. Protractors are made of cardboard, horn, brass, German silver, steel, hard rubber, and celluloid.

The simplest form, shown in Fig. 8, consists of a semicircular sheet. The straight edge is parallel to the diameter of the arc, and the center is plainly marked by a line. The edge is divided to degrees which are numbered in both directions. Protractors of this type vary in diameter from about 5 inches to 14 inches, the larger ones being divided to $\frac{1}{4}$ degrees. Cardboard protractors are usually rectangular in form when bought. It is best to cut around

the curved portion, but to leave the edge parallel to the diameter and cut a notch to the center as shown in the figure. The center and ends of the diameter will then be protected from wear. When harder material is used, the instruments are made to the outline of the arc and diameter.

A type of the more accurate form of protractor is shown in Fig. 9. German silver is the material commonly used. The arm A is pivoted at the center of the arc, and a thin disk of horn with two cross lines ruled upon it accurately marks this center. The beveled edge of the arm is accurately radial. The arc or "limb" is divided to $\frac{1}{4}$ degrees, and a vernier V is engraved on the arm, by the use of which the latter can be set to read to single minutes of the arc. This form is called a vernier protractor, and is made also with a full circle.

For methods of protracting angles see Art. 86.

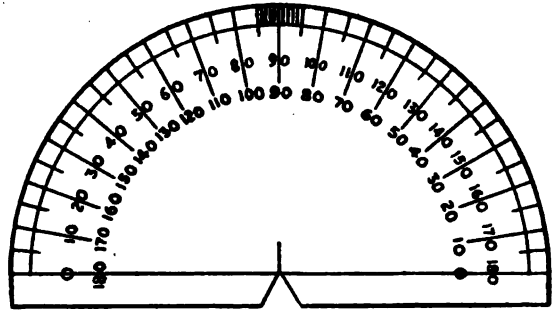


Fig. 8.

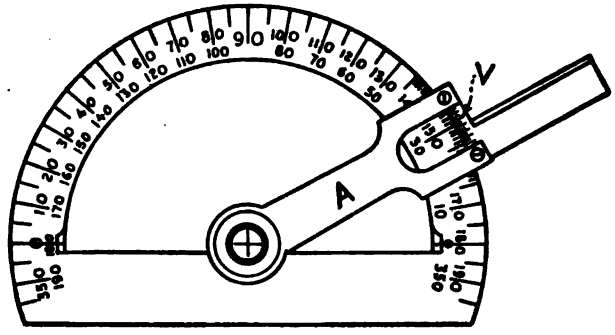


Fig. 9.

10. Section Liner. This instrument may be classed as a luxury, but it is very convenient, especially in finishing the cross sections of structures. It is simply for drawing parallel, equidistant lines. Of course a draftsman should be able to do this well with only a pair of triangles and a ruling pen, without first laying off the equidistances. But having acquired the ability to do this he may consider legitimate the use of a section liner. Of the many forms of this instrument on the market the Both Section Liner is satisfactory and is probably best known. This is shown in Fig. 10. The base B is a bar about 15 inches long with a rack R fastened to it and extending to within about 3 inches of the ends. In use this base is held down firmly by weights placed on the ends. When the knob K is pressed down, the pawl P, which engages the teeth of the rack, causes the carriage C to move forward to the right. Attached to the rear of the carriage are the arc A and the ruler E. When the pressure on the knob is released, a spiral spring throws it up against the check nut N, the pawl is drawn forward one or more notches of the rack, and all is ready for a repetition of the forward motion of the carriage and its attachments. The teeth in the rack are $\frac{1}{24}$ inch apart, and the number of them passed over by the pawl at each pressure on the knob depends upon the amount of vertical travel allowed in the latter by the position of N.

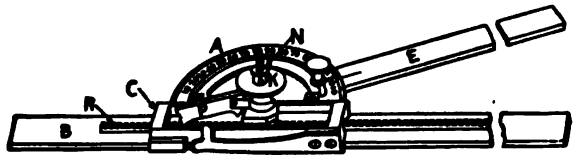


Fig. 10.

If the pawl passes over one notch at each operation, the carriage, and consequently the ruler, will move forward $\frac{1}{24}$ inch, and corresponding multiples of this distance for greater numbers of notches. At each successive position of the ruler a line is drawn along its edge with an ordinary ruling pen.

When the ruler is set at 90° with the base, it is evident that the successive parallel positions of its edge will be distant from one another an amount equal to the successive movements of the carriage, that is, $\frac{1}{24}$ inch for each notch passed over. If, however, the ruler is set at a smaller angle with the base, the perpendicular distances between the ruled lines will be less than $\frac{1}{24}$ inch. If the angle is 30°, the lines will be equidistant $\frac{1}{24} \times \sin 30° = \frac{1}{24} \times \frac{1}{2} = \frac{1}{48}$ inch. Usually the converse of this operation is required, namely, to find the setting of the ruler on the arc for a desired distance between the ruled lines. To solve this case find the natural sine of the required angle by dividing 24 (the number of teeth per inch on the rack) by the required number of lines per inch. Thus for 50 lines per inch, $24 \div 50 = 0.48$, which is the natural sine of 28°−41′, the required angle. If fewer than 24 lines per inch are required, the pawl must be set to pass more than one notch, and the proper substitute made for 24 in the above equations.

11. The Planimeter. This is an instrument for measuring areas, and is particularly useful in engineering work because the areas of irregular figures are found as easily and accurately as those of regular figures. The drawing from which the measurement is made must of course be accurately drawn to scale.

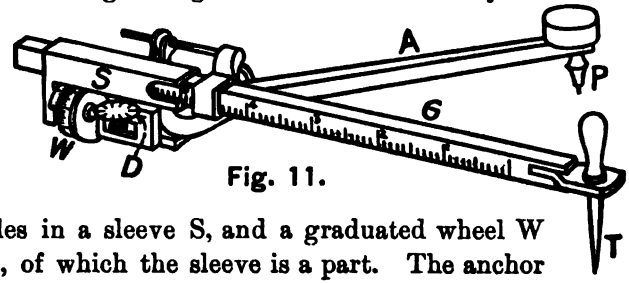


Fig. 11.

The instrument consists in its simplest form, Fig. 11, of an anchor arm A of fixed length, a graduated arm G which slides in a sleeve S, and a graduated wheel W carried on an axle fixed to the framework, of which the sleeve is a part. The anchor

point P is thrust into the drawing and the whole instrument rotates about it. The only other points in contact with the paper are W and the tracing point T.

The usual and most simple method of using the planimeter is to place P outside the boundary of the area to be measured.* T is then moved carefully right-handed around the boundary. W rolls on the drawing, and the total amount of its rotation is read at the vernier. As usually adjusted $\frac{1}{10}$ rotation of W represents one square inch of area on the drawing. (See also Arts. 27 and 28.)

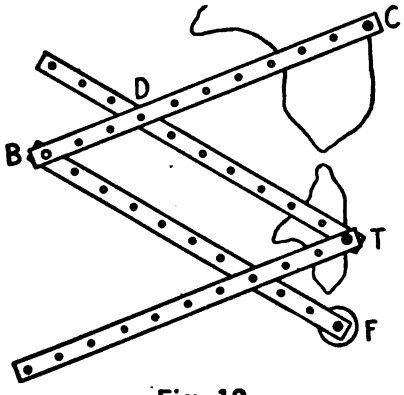


Fig. 12.

12. The Pantograph. This instrument is for copying drawings either to the same, a reduced, or an increased size. Its essential parts are shown in Fig. 12. The necessary conditions are that the four bars shall, by their intersections, form a parallelogram, and that F, T, and C shall be in a straight line. The instrument moves about the fixed point F. T is a tracing point which is moved along the lines of the figure to be copied, and C is a pencil point which does the copying. The ratio of linear dimensions in the copied and original figures depends upon the manner in which the bars are put together to form the parallelogram, and may be expressed thus: $\frac{CB}{CD} = \frac{FB}{TD}$ = the scale of enlargement. If a reduction is required, the

* For the method of measuring large areas with the anchor point inside the boundary see Raymond's "Plane Surveying" or Johnson's "Theory and Practice of Surveying."

tracing and copying points must be exchanged; if a copy to the same scale is required, the arms must be arranged so that $\frac{CB}{CD} = 2$, and T must become the fixed point.

The cheap pantographs are made of wood, and usually are not very accurate. The expensive instruments are made of brass or steel, and have many devices to secure accuracy and convenience of operation.

13. The Copying Glass. A panel of glass, suitably mounted, and illuminated from below, is found most useful in the drafting room. An excellent form of such a "copying glass" is shown in Fig. 13. The panel is of plate glass, about 2×3 feet in size, set into and flush with the top of a drawing table. Below is a hopper-shaped box of wood with the sides at 45° with the horizontal, painted white. Electric lamps are placed in the bottom, some of the light from which directly illuminates the glass, and some is reflected upward from the sloping sides of the box, thus giving an even illumination to the whole panel.

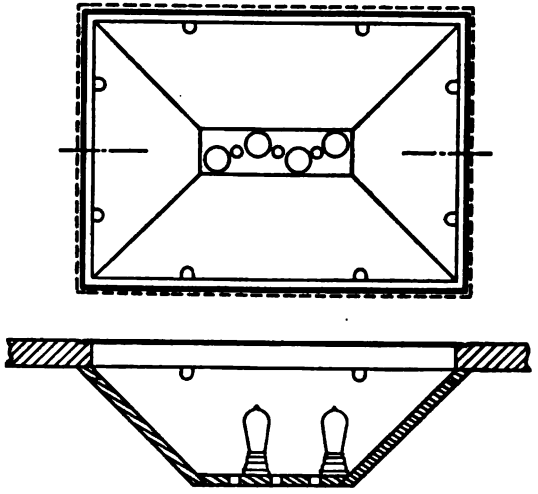


Fig. 13.

To prevent the glass from getting very hot, air is allowed to circulate through holes in the bottom of the box and at the top of the sides. But the glass gets hot enough to expand

considerably, and should not be made to fit tightly into the table. One side of the box should be hinged to allow access to the lamps.

By the use of the copying glass, drawings may be copied, by simply tracing on paper through which, ordinarily, the lines of the original drawing would not be visible. But by illuminating the back of the latter its lines are made visible through very thick paper.

14. Straightedge. A necessary implement for accurate drawing is a steel straightedge. This is simply a strip of steel, nickel plated, about $\frac{1}{16}$ inch thick, with the opposite long edges perfectly straight and parallel. Straightedges vary in length from 15 to 72 inches, and in width from $1\frac{1}{8}$ to 3 inches. There is a hole near one end for hanging the instrument up when not in use, — a precaution which should not be neglected, as otherwise the edge is very likely to get nicked, or the steel sprung out of shape. The 36-inch length is probably best suited to ordinary work.

The straightedge is used not only for the actual drawing of long lines, but also as a base upon which a triangle is worked.

15. Needle Point or Pricker. This is simply a fine needle held in any convenient handle. Dealers sell for this purpose handles having a socket at the end for holding the needle. Usually, however, the instrument is made by the draftsman. A *fine* needle is broken so that about $\frac{3}{4}$ inch of the pointed end remains. This is grasped in a pair of pinchers and the blunt end is forced into the end of a stick of soft wood whittled to the diameter of a pencil, leaving about $\frac{1}{4}$ inch of the pointed end of the needle exposed. The stick is then tapered at the needle end, and at the opposite end, for about two thirds of its length, it is flattened on opposite sides

so as to be wedge shaped; this is to prevent the instrument from rolling off any inclined surface upon which it may be placed. The handle is more easily kept clean if it is shellacked.

16. Paper Weights. Various forms of weights for holding down paper, straight edges, etc., are sold. A very neat form is a cylinder of lead about $2\frac{1}{2}$ inches in diameter and 1 inch high. This is inclosed in a tin case which is covered with felt. A very satisfactory form is more simply made by filling canvas bags with shot. These should be about $2\frac{3}{4}$ inches square, and contain about 3 pounds of shot.

17. Paper. An important difference in papers depends upon the method of manufacture. **Machine-made paper** is formed by an endless belt, usually of cloth, which moves through a long trough containing water and picks up the cotton, linen, or wood fibers which are suspended in it, and of which the paper is to be made. The currents formed by the belt moving through the water cause most of the fibers to be arranged on the belt parallel with its length. In some papers the imprint of the weave of the belt may be seen on the "wrong" side. When paper thus made is dampened it behaves much as a board does when wet, and for the same reason. The water gets between the fibres (which are long and slender) and crowds them apart. Thus the paper is considerably expanded in the direction perpendicular to that along which most of the fibers lie, and only slightly expanded along the length of the fibers.

In **hand-made paper** the fibers cross each other in all directions, and when such paper is dampened, it expands nearly equally in all directions, and is therefore especially valuable for fine drawings.

The best-known hand-made paper is **Whatman's**. The sheets are sorted, those having imperfections are called "Retree," and the perfect ones "Selected Best." They are also classified as "Hot Pressed," or simply "H," and "Cold Pressed." The hot-pressed sheets have a relatively smooth surface on which a fine pen can be used. The cold-pressed sheets have an open, fibrous surface especially adapted to work in water colors. They are further classified as "Not Hot Pressed," or "N," and "Rough," or "R," the latter being a very heavy paper with a decidedly rough surface which gives a beautiful effect to color washes in large areas.

Large sheets of Whatman paper are thicker than small ones, and for color work on small sheets it is advisable to cut large sheets into pieces of the desired size.

While Whatman paper has nominally a right side, as shown by the watermark, yet either surface may be used.

The following designations of sizes, while commonly associated with Whatman paper, are applicable to all other papers: —

Cap, 13 × 17 in.	Royal, 19 × 24 in.	Atlas, 26 × 34 in.
Demy, 15 × 20 in.	Super Royal, 19 × 27 in.	Double Elephant, 27 × 40 in.
Medium, 17 × 22 in.	Imperial, 22 × 30 in.	Antiquarian, 31 × 53 in.

Other papers suitable for fine line work are Leonine, Weston's Linen Record, and Keuffel & Esser's Normal. Eggshell paper has a hard surface containing slight indentations, and is effective if lines are not too fine. Keuffel & Esser's Paragon takes water colors fairly well.

Cross-section Paper, Fig. 19, is in sheets about 16 × 20 inches and in rolls 20 inches wide. The best sheets are printed from plates ; the inferior sheets and the rolls are machine ruled. The surface is divided into squares by heavy lines, the sides of the squares being 1 in., $\frac{1}{10}$ ft., or 1 centimeter. These squares are subdivided into smaller squares by fine lines, each side being $\frac{1}{8}$, $\frac{1}{10}$, $\frac{1}{12}$ inch, $\frac{1}{100}$ foot, 1 millimeter, etc. There are several other systems of division for special purposes. The ruling is in blue, green, or orange, the latter being used mostly on thin paper for blue printing.

For topographical work the paper divided into $\frac{1}{10}$ inch squares is most generally useful. It has a great variety of uses, the most common of these in topography being in making studies of sloped embankments and cuts, and in showing sections of grading of all kinds. When a planimeter is not at hand, cross-section paper is sometimes used for finding areas within irregular outlines, by counting the squares and fractional parts of squares within the outline.

This paper is also called " squared " and " quadrille " paper.

Profile paper is like cross-section paper except that the horizontal and vertical divisions are to different scales ; thus the surface is divided into rectangles instead of squares. " Plate A " has 4 divisions per inch horizontally and 20 vertically. The corresponding divisions for " Plate B " are 4 and 30, and for " Plate C " 5 and 25. The ruling for Plate A is shown in Fig. 46. This paper is used for plotting profiles (Art. 107) or other sections where the differences in surface elevation are slight. Profile paper can be bought in sheets, but is more common in rolls 20 inches wide. The ruling is on heavy paper in green or orange, and on tracing paper in orange.

Transfer paper may be made by going over the surface of thin paper with a very soft pencil, and then rubbing with a chamois stump or piece of blotting paper to distribute the

"lead" more evenly; or the pencil may be ground on a file, and the filings rubbed over the thin paper. This paper may be used to copy drawings that are made on fairly thin paper, as described in Art. 143.

Tracing paper is thin, translucent paper which affords a means for making copies of drawings rapidly by simply tracing the lines. This paper is usually deficient in strength and in erasing qualities, and should be employed only for studies or for temporary use. It is sold in rolls, and is from 37 to 54 inches wide.

Tracing cloth is a prepared muslin, transparent, and very strong. It is used in the same way as tracing paper except that, if ink is to be used, as is commonly the case, the surface must be rubbed with some substance to remove an imperceptible greasy coating. For this purpose common chalk dust is as good as anything. Either side of the cloth may be used. Two, or even three, erasures may be made if done carefully with a good eraser. A knife should not be used. The surface is left rough after an erasure, and will soon become dirty if left in that condition. To restore the smoothness scrape a little dust from a piece of talc on the rough place and rub it in briskly with a clean cloth.

Pencil marks may be quickly removed by rubbing with a cloth wet with benzine or gasoline, which, however, will not injure the inked lines. (See also Art. 133.)

18. Pens and Holder. A variety of pens will be needed. No list can easily be made to suit all experienced draftsmen, but the following, arranged in the order of coarseness, will do for the beginner: Gillott's mapping pen No. 291, Spencerian epistolaire No. 12, Gillott's Nos. 170, 303, 404.

The penholder should be not less than $\frac{3}{8}$ inch diameter at the point where it is grasped by

the fingers, and this portion of it is best made of cork. A holder with a smooth, metallic ferrule at the lower end should never be used.

19. Brushes. For color work two brushes, one a double-end brush, will be needed. The best round camel hair brushes in albata ferrules are recommended. Finer grades are made of red and black sable. Suitable sizes are shown in Fig. 14. (It should be remembered that a full-size drawing of an object looks larger than the object.) Brushes are numbered according to sizes, but the numbering is not standard. The handles should preferably be simply polished, not painted. Brushes should be thoroughly washed in clean water before the color can dry in them, and laid away flat, with the end formed straight and pointed.

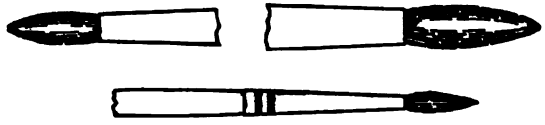


Fig. 14.

20. Water Glass. The best form of water glass has lips on opposite sides of the rim. These furnish a convenient place for laying the brush when it is temporarily out of use. A common tumbler should also be provided for holding water in which to clean the brushes.

21. Color Saucers. For preparing the colors a "nest" of six "cabinet" saucers about $2\frac{1}{2}$ inches in diameter is most convenient. These saucers fit each other closely, so that any saucer may serve as a cover for another. This is a convenience when it is desired to protect the colors from evaporation for a time. Select saucers which are decidedly concave.

22. Colors. The most convenient pigments for color work are the moist colors in porcelain pans. Those made by Winsor and Newton are always of good quality. For students' use the "half pans" will be found large enough.

The colors should include Yellow Ochre (Y.O.), Gamboge (G.), Crimson Lake (C.L.), Burnt Sienna (B.S.), Prussian Blue (P.B.), Payne's Gray (P.G.), Sepia (S.), and Burnt Umber (B.U.). Chinese White will occasionally be found useful. The tube form of this pigment is preferable, since that contained in pans becomes very hard.

23. Colored Pencils. In drafting offices considerable use is found for colored pencils or "wax crayons." They are usually known by number, but each maker uses his own scheme of numbering. The following list gives a fair assortment, the numbering being that of A. W. Faber : 2, yellow ; 13, blue ; 30, sienna ; 38, vermilion ; 54, purple ; 62, orange ; 63, light green ; 69, dark green.

For uses see Art. 94.

CHAPTER II

PRELIMINARY PROBLEMS AND OPERATIONS

24. To divide a given distance into equal parts. The usual geometrical construction is shown in Fig. 15. Let it be required to divide the line AB into five equal parts. Draw AC at any angle with AB, and from A lay off five equal spaces of any length, and connect the last point, 5, with B. Parallels to 5B through the other points of division will intersect AB in the required points.

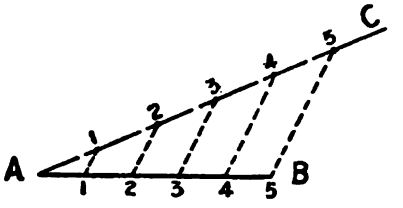


Fig. 15.

It is often necessary to interpolate the number of equidistant parallels between two given parallels, as in drawing contours for slope grading (Art. 112). If the given parallels are practically straight lines, a ready means of making the division is shown in Fig. 16. Place a scale of equal parts diagonally across the lines so that the latter will intercept the required number of divisions on the scale (5 in the figure), and place a point close to the edge of the scale at each required point of division.

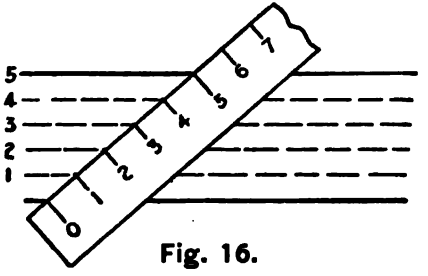


Fig. 16.

25. To divide an arc into equal parts. If the center of the arc is accessible, a protractor may be used to lay

off arcs subtended by the required divisions, and lines may be drawn through the extremities of the protracted arcs and the center, and extended to the given arc.

When the center is not accessible, the following method may be used, especially if the number of divisions is large. Let it be required to divide arc AB, Fig. 17, into eight parts.

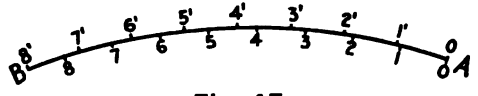


Fig. 17.

With the large dividers (or a scale if the distances are too great for dividers) lay off from A eight equal parts, 1, 2, . . . 8, such that 8 falls short of B. With the small dividers find by trial $\frac{1}{8}$ of the distance 8 B, and lay this off once from 1, twice from 2, etc., giving the points 1′, 2′, . . . 8′, which are the required points of division. This method requires less time, and injures the paper less than would be the case if the whole arc were divided by a series of trial openings of the large dividers.

26. To find points on an arc of large radius. It is sometimes impossible or inconvenient to draw a circular arc of large radius with beam compasses or a railroad curve. The arc may otherwise be drawn by finding a number of its points and joining them. In Fig. 18 let AB be a chord of the required arc of radius R. Draw A0 and B6, each making with AB an angle whose sine $= \frac{\frac{1}{2}\,AB}{R}$. These lines are tangents of the required arc. From A and B as centers, with

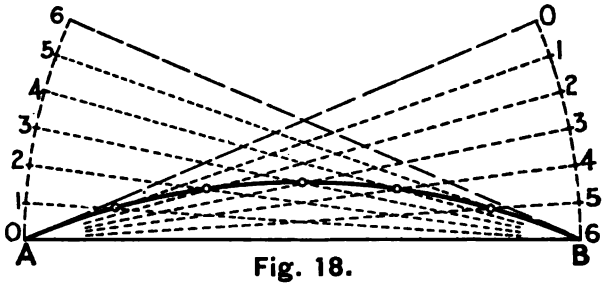


Fig. 18.

radius AB, describe arcs cutting the tangents in 0 and 6. Divide the arcs into any number of equal parts, as 6, and number them in reverse order from the chord, as shown. The intersections of A1 with B1, A2 with B2, etc., will give points on the required arc. These may be joined either by means of a ship curve, or by the use of a railroad curve which closely approximates the arc, or by springing a steel straightedge (held edgewise to the paper) so that it passes through the points.

27. Multiplier for Planimeter Measurements. In the use of the planimeter as described in Art. 11, the instrument measures the number of square inches of paper included within the boundaries of the drawing. But the relation between this area and the area of the surface *represented* by the drawing obviously depends upon the scale of the drawing. If, for instance, the scale is 1 inch = 40 feet, each square inch of drawing represents $40 \times 40 = 1600$ square feet of surface represented, and the planimeter record of total area in *square inches* should be multiplied by 1600 to obtain the area in *square feet* of the surface represented. The constant multiplier, then, is **the square of the number of linear feet represented by one linear inch on the drawing.**

Find the multipliers, to obtain square feet, for the following scales: 1 inch = 80 feet, 1 inch = 3 rods, 3 inches = 1 foot, $\frac{1}{16}$ inch = 1 foot.

28. Rating the Planimeter. In the form of planimeter shown in Fig. 11, the graduated arm G can be slid in the sleeve S, so that the distance WT can be changed. Sometimes the arm G, instead of being divided into many equal parts, as shown, has marks upon it corresponding to the various scales ordinarily used in making plans. The appropriate mark, when set against a scratch shown in the opening at the end of S, will enable the instrument to be

used without the multiplier explained in the last article. While this is a convenience, it is not an advisable method of graduating the arm, because in time the wheel W becomes worn so that its circumference is sensibly changed, and a corresponding change must be made in the distance WT to compensate for the wear.

The determination of the proper setting of the arm with reference to the index mark on the sleeve is called "rating the planimeter."

A method of rating may be explained by reference to Fig. 19. A square of, for instance, 4 inches on a side, is first very accurately drawn on a smooth sheet of paper. The arm of the instrument is set at random and the tracing point is passed very carefully around the sides of the square. Suppose the setting of the arm to have been 144 and the reading of the wheel 15.7. Now, as shown in the figure, plot the 144 as abscissa and the 15.7 as ordinate, and thus obtain point A. Make another setting of the arm, obtain another reading for area, and plot the results as before, obtaining the point B. These results show that the arm is still too short, as both readings for area are less than 16, the true area of the square. Use other settings of the arm, some of which shall give area readings of more than 16. Draw a straight line AC among the points thus plotted. The horizontal line through 16 (the true area of the square) intersects AC at D. From D draw the vertical DE. This cuts the base line at 148.3 which is the required setting of the arm.

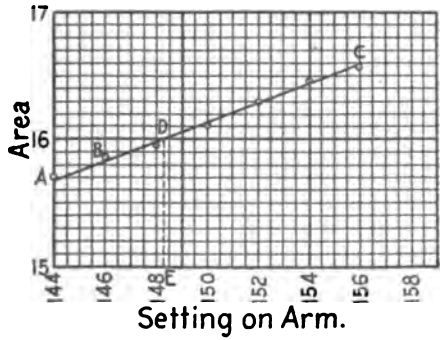


Fig. 19.

Squares of other sizes may be used to get additional determinations (which should be substantially like the first), and the mean of results taken as the true setting. If any one result is widely at variance with others, it indicates an error in drawing the square.

A variation of this method consists in measuring a circle instead of a square. This can best be done as follows: near each end of a strip of firm cardboard prick a fine hole, the distance between the holes being carefully determined. Through one of these pin the strip down to a sheet of smooth paper on the drawing board, by a short piece broken from a fine needle. Place the tracing point of the planimeter in the other hole and cause the strip to rotate about the needle. The tracer will thus be made to traverse the circumference of a circle whose radius is the distance between the holes, and whose area can be computed. Some instruments are supplied with a strip of metal to be used as here indicated for the cardboard.

The anchor point P, Fig. 11, should be so placed, relative to the figure to be measured, that the point T need not be brought very near to it in traversing the boundary, otherwise the instrument will not stand firmly.

It is sometimes found that with the anchor point in different positions relative to the boundary of the figure different areas are obtained. This indicates a lack of adjustment in the parts, and the instrument should be sent to the maker for adjustment.

29. Stretching Paper. Paper upon which any considerable amount of water coloring is to be done must be stretched, otherwise the moisture of the colors will cause it to wrinkle or "cockle," and the color will not dry smoothly.

Lay the sheet to be stretched face upward upon a larger sheet of clean manila paper and with a soft sponge and clean water dampen the surface. Turn the paper over and dampen the

back to the edges, uniformly and thoroughly. When it lies perfectly limp, take up as much water as possible from the margins, with the sponge squeezed dry, and spread glue or strong mucilage thinly for a width of ½ inch around the edges. Place the sheet with the glued surface downward upon the drawing board, and press the edges downward and gently outward till the sheet is smooth. With a smooth, blunt object, such as the end of a knife handle, rub the edges down, using as much pressure as the dampened paper will bear.

Meanwhile keep the paper expanded by more water, but be careful not to go within an inch or more of the edges, otherwise the glue will be prevented from hardening. The board must be perfectly level so that the water on the surface will not run to the edges.

Continue to rub down the edges and to keep the paper expanded till the glue has firmly set. Take up any superfluous water and allow the sheet to dry, still in a horizontal position.

On first dampening the paper the surface may be gently rubbed with the sponge, but after that it should be patted.

It is a mistake to suppose that a great deal of water is needed to expand the paper, as will be seen when it is remembered that a very noticeable expansion is caused by the moisture in the air on a damp day.

The drawing board for stretching paper should be shellacked, as this prevents the paper from being stained by the wood, and prevents the glue from sinking into the grain, with the probable result that some portions of the edges will not be well secured. Old, weather-stained wood is sure to leave brown stains which cannot be removed.

Care must be exercised that the paper is not glued to the board at any point except at the edges.

30. Mounting Paper on Cloth. The durability of a drawing is much increased by applying a backing of cloth. Whatman and some other papers grow tender with age, and should be backed with cloth, or "mounted," if they are to be subjected to much handling. It is better to mount the paper before the drawing is made, especially if water coloring is to be done. Lithographs, photographs, blueprints, in fact all sorts of drawings, prints, and engravings are mounted to make them more available for continued use.

Only bleached cotton cloth is used for mounting. The piece should be at least an inch larger all around than the paper. With small tacks fasten the cloth to the drawing board, beginning always at the middle of a side, and working equally each way. Tack down the long edges first, and pull the cloth in each direction with a force a little greater than enough to make it simply smooth. Expand the paper by moisture, apply starch paste (never mucilage or glue) to its back, and lay carefully face up on the cloth. Press it down with a rubber roller, or (after having covered it with another sheet of cloth or paper) with the flat of the hand. In either case begin at the center and work toward the edges so that all air shall be pressed out.

Since the whole of the back is covered with paste, it is not necessary to keep the paper expanded till the paste dries. Be careful to apply plenty of paste to the edges of the paper. If the paper is thin, the paste alone will expand it.

It is a wise precaution to lay a single thickness of newspaper between the cloth and the drawing board, otherwise the paste will sometimes strike through the cloth in spots, and cause it to stick to the board, thus producing a wrinkled area in the finished work.

Paste suitable for mounting paper may be made as follows: to one fourth cupful of common laundry starch add as much flour as will be contained in the interstices of the lumps;

add a very little cold water, — only enough to make a paste of the starch and flour, and with the back of a spoon grind the paste smooth; then add enough more cold water to thin the paste so that it will run freely from the cup. Three cupfuls of water should meanwhile have been brought to the boiling point in an open saucepan. Still keeping the saucepan over the fire, pour the paste slowly into the boiling water, and stir very briskly with a spoon. Let the mixture boil for a minute or two, then set the pan into a large dish into which cold water is allowed to run. While the paste is thus cooling, stir it slowly to prevent the formation of a hard coating on top.

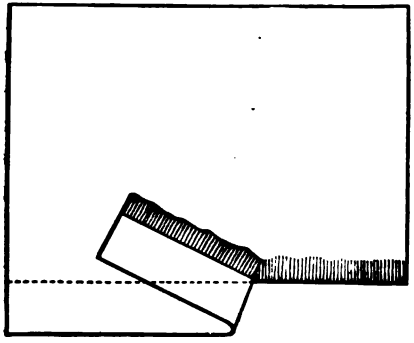


Fig. 20.

A flat bristle brush is best for spreading the paste, which should be applied liberally and evenly. The quantity here given is sufficient for about thirty-six square feet of paper.

31. Splicing Paper. It is often necessary to join two or more pieces of paper, especially when mounting on cloth. If the edges of the sheets are simply lapped, the joint will be clumsy, particularly if the paper is thick; but if the edges are first beveled, a better joint will be secured.

Beveling may be done as follows: lay the paper on a smooth, hard surface (glass is best), and with a *sharp-pointed* knife cut along a straight edge where the edge of the sheet is to be. This cut must extend only through the "skin" of the paper, and should be of equal depth in every part. Turn the sheet over and tear off the edge, holding it in relation to the sheet as shown in Fig. 20.

The thickness of the thin edge of the beveled portion will be determined by the depth of the cut, and the width of the bevel will depend upon the angle at which the edge of the marginal strip is held relative to the edge of the sheet while the tearing is in progress; the more nearly parallel the edges are, the less will be the width of the bevel. Of the two sheets which are to be lapped at their beveled edges, the one which overlaps should have the cut on the right side, while the one which underlaps should have it on the wrong side. If the lap is greater than the width of the bevel, the torn surfaces will be completely hidden.

The tearing should be practiced on a waste piece of paper of the same kind as the sheets to be joined.

32. Patching Tracing Cloth. Tracing cloth will not stand a great deal of erasing, and if more than one erasure is made at the same place, the cloth often breaks. Such a rent should be patched. With an ink eraser clean the back of the tracing for a short distance from the edges of the rent. Have ready a piece of tracing paper considerably larger than the desired patch. With the end of the finger rub paste evenly and thinly over the area of the cloth cleaned with the eraser, apply the tracing paper, and rub it down. When the paste is thoroughly dry, tear away the superfluous paper on a bevel as described in the last article. In this case the outline of the patch is an irregular line defined by the edge of the pasted area, instead of a knife cut.

Blueprints made from a patched tracing will show lighter blue where the patch occurs, but the beveled edge of the patch causes the outline of this lighter area to be indistinct.

CHAPTER III

PLOTTING

33. The General Problem. The object of plotting is to transcribe to paper, to a suitable scale, such data as are necessary to convey clearly certain ideas concerning areas of the earth's surface and surveys which may have been made upon it. These data include the following: the boundary lines of the portion of land under consideration; such arbitrary lines as may have been used in the survey; the imaginary lines joining certain points of equal elevation (*i. e.* contours, Art. 109); and a representation of the natural and artificial features — bodies of water, trees, buildings, etc. — that occur within the boundary. Not all of these are shown in each instance, the purpose of the drawing determining the amount of detail.

The process of locating these lines and objects in their proper magnitudes and relations is called **plotting**.

34. Plotting a Triangulation. Every figure whose boundaries are composed of straight lines may be divided into triangles; and one of the most accurate field methods of determining the relative positions of points on the earth's surface is by **triangulation**. By this process the objects to be plotted are made the vertices of triangles, the angles of which are measured very accurately, and the lengths of whose sides are computed, — except the first side, or base, of a series of triangles, which is measured. The most direct way of plotting such triangles is

by first laying down the base line to scale, and from its ends swinging intersecting arcs with radii respectively equal to the other two sides of the triangle, thus locating the vertex opposite the base. The sides of this triangle may in turn serve as bases.

35. Plotting Progressive Angles. More commonly the lines to be plotted run as consecutive sides of a polygon, whose sides have been measured and the angles between which are known. In plotting these the sides may be scaled on the paper and the angles laid down in their order. The more difficult part of this process is the plotting of the angles, for which some methods are given below.

36. Protracting an Angle. If extreme accuracy is not required, the angle may be laid off by means of a protractor (Art. 9), as this is the quickest and most convenient method. Draw to scale the first side of the angle, and if this is not as long as the radius of the protractor, extend it backward from the end where the vertex of the angle is to be; also extend it forward from the last-named point a distance slightly greater than the radius of the protractor. Place the protractor upon this line with its diameter coincident with it, and its center at the vertex point. If the protractor is simply a graduated arc, prick off the required angle at its edge, and join this point with the vertex point for the second side of the angle; if it is a vernier protractor, turn off the required angle with the arm and draw a fine line along the latter, and extend this line to the vertex point.

The angle may be turned off on the vernier protractor either before or after setting it on the line; but in either case see that the protractor, as a whole, and the arm are properly placed before drawing the line along the arm.

37. To plot an Angle by its Tangent. This method is suitable for plotting angles of less than 45° and more than 135°. Acute angles are plotted directly, and obtuse angles are obtained by plotting their supplements.

Let it be required to plot an obtuse angle a, Fig. 21, one side of which is AB. Extend AB to C, BC being a measured distance. On the perpendicular CD lay off CE = BC × tan $(180° - a)$, and draw EB for the second side of the angle.

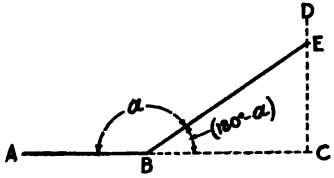


Fig. 21.

A convenient length for BC is 10 inches, for if a table of natural tangents be used, the value of CE is obtained at once by moving the decimal point one place to the right. For very accurate work, however, a greater length is advisable.

38. To plot an Angle by the Chord of its Subtended Arc. When the angle to be plotted directly is greater than 45°, the method here given is preferable to that given in the last article.

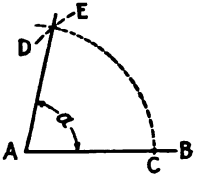


Fig. 22.

In Fig. 22 let AB be one side of the required angle a. With radius AC describe an indefinite arc from A as center. From C as center describe arc DE intersecting the first, the radius R of DE being found by the equation $R = 2\left(AC \times \sin\frac{a}{2}\right)$. Join the intersection of the two arcs with A for the second side of the required angle.

39. Defect of Plotting Progressive Angles. The defect of the method of progressive angles is that the position of any line of the polygon depends directly upon that of previous

sides; thus an error in any side is carried into all succeeding sides. If the sides form a closed figure, the error will be detected by the failure of the plot to "close," and all the work succeeding the point at which the error occurred must be corrected. If the courses do not form a closed figure, the error may escape detection.

It is obvious that it is desirable to plot by methods which shall confine the effects of an error to the course wherein the error is made. The following methods are designed to attain such a result, as well as to provide a high degree of accuracy.

40. Deflection Angle. The angles to be dealt with in plotting will depend upon the method pursued in the survey. If it is a small, closed polygon that has been surveyed, it is probable that the **deflection angle** between the sides or "**courses**" will have been measured. This angle is the one between one course extended beyond the angle point and the following course. Thus in Fig. 21 the angle EBC is the deflection angle between courses AB and BE. The interior angles (a in Fig. 21) are the supplements of the corresponding deflection angles, and a proof of the accuracy of the measurements for a closed polygon of n sides is that the sum of the interior angles shall be 180° taken as many times, minus two, as the figure has sides; or, **sum of interior angles** $= (n-2)\ 180°$. Since at each angle of a polygon the interior and deflection angles together equal 180°, the total of such angles is $n \times 180°$; but since the total of the interior angles is $(n-2)\ 180°$, **the sum of the deflection angles** $= (n \times 180°) - (n \times 180° - 2 \times 180°) = 360°$, whatever the value of n; and this furnishes a ready check upon the field work. This is not true, however, when there are reëntrant angles, as at C, Fig. 24.

Deflection angles are **right** (marked simply r), or **left** (l), depending upon their position with respect to the first side produced. Thus in Fig. 21 the deflection angle EBC is l,

since it lies to the left of AB produced. In Fig. 24 all deflection angles are *r* except that at C. But if we go around the figure in the direction contrary to that indicated by the order of the letters, all deflection angles are *l* except that at C.

41. Bearings. When the survey is made with a magnetic compass, the bearings of the courses are taken, that is, the acute angles which the several courses make with the magnetic north and south line. The bearings of courses should not be written indiscriminately ; in Fig. 23 it is seen that the bearing of BC may be written N 74° E with reference to the meridian through B, or it may be written S 74° W with reference to the meridian through C. In writing the bearings it should be assumed that the survey proceeded consecutively in one direction, and the bearing of each course should then be with reference to the meridian through its point of beginning.

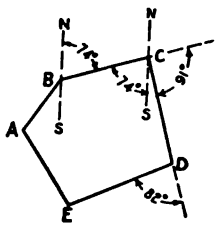


Fig. 23.

Of course the bearings may be given with reference to the true meridian rather than the magnetic, and the plan should indicate which meridian is used. This is usually done by drawing a north point and marking it "True Meridian" or "Magnetic Meridian," as the case may be.

It is not necessary that the actual bearings of all courses be determined in the field, for if the bearing of one course be known, the bearings of the other courses may easily be determined by a proper use of the deflection or included angles between courses. Thus in Fig. 23, knowing the bearing of BC to be N 74° E, find the interior angles and the bearings of the other courses from the following deflection angles, beginning at C and proceeding in right-hand order : 91°, 82°, 80°, 68°, 39°.

A survey may be made without reference to either the magnetic or true meridian, and for purposes of plotting and computation of area the bearings of the courses may be found with reference to one of the sides or to an arbitrarily chosen line, this line then being used as if it were really a meridian. Bearings thus computed from an assumed reference line are called **false bearings**. Some labor is saved by using one of the courses as the assumed meridian.

42. Azimuth. The azimuth of a course is the total angle which it makes with the meridian, whether this angle is acute or obtuse. There is no general agreement among surveyors as to whether the azimuth should be read from the south by way of west, north, and east; or from the north in the same direction. Of course, in a single survey one or the other of these methods should be adhered to. In Fig. 23, if readings are made from the north, the azimuth of BC is 74°; if from the south, it is $180° + 74° = 254°$. It will be seen that there are relations between interior angle, deflection angle, bearing, and azimuth such that if the directions of courses be given by any one of these methods, their directions may be expressed by any other method, though it may be necessary to use false bearings or azimuths

43. Plotting by Total Latitudes and Longitudes. This is an excellent method for several reasons, viz. that great accuracy is possible; an error in plotting one course is not carried into succeeding courses; few auxiliary lines are needed, and these do not cover a large area outside that required for the finished plot.

For illustration let the following notes of a closed polygon of 6 sides be considered: —

Course	Length, Feet	Bearing
AB	1070.00	S. 72°-20′ E.
BC	845.40	S. 32°-40′ W.
CD	482.00	S. 35°-20′ E.
DE	1107.00	S. 71°-50′ W.
EF	1216.68	N. 29°-29′ W.
FA	1080.00	N. 48°-30′ E.

A free-hand sketch of this, Fig. 24, shows that the most westerly point occurs at F, the junction of EF and FA. This fact also appears from an inspection of the bearings in the table.

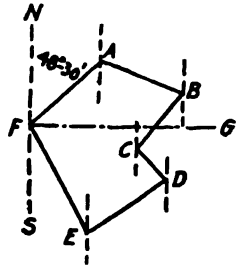


Fig. 24.

If through F a meridian NS and a horizontal line (parallel of latitude) FG be drawn, these lines will be axes from which the corners of the polygon may most conveniently be plotted.

The table of latitudes and longitudes given below is next computed. This, in practice, may be an extension of the table given above. Since the plotting will be done from axes through F, course FA is the first one used in making columns 4 and 5. The **total latitude** of a point is simply the distance of the point above or below the axis FG, and the **total longitude** is the distance to the right of the meridian through F; hence, beginning with FA, the total latitude and longitude of A are the same as the latitude and longitude respectively for course FA, and the total latitudes and longitudes of the successive points B, C, D, etc., are obtained by adding *algebraically* the successive latitudes and longitudes, beginning with course FA as indicated.

The proof of the correctness of the last two columns is that the total latitude as well as the total longitude of point F (the forward extremity of EF) is zero, as it should be, since the point is at the intersection of the axes.

Course	Latitude Length of Course × cos Bearing	Longitude Length of Course × sin Bearing	Total Lat.	Total Lon.
AB	− 324.72	+ 1019.30	+ 390.91	1828.17
BC	− 711.68	− 456.30	− 320.77	1371.87
CD	− 393.21	+ 278.76	− 713.98	1650.63
DE	− 345.14	− 1051.82	− 1059.12	598.81
EF	+ 1059.12	− 598.81	0.00	0.00
FA	+ 715.63	+ 808.87	+ 715.63	808.87

To make the final plot two axes are drawn accurately perpendicular to each other, corresponding to NS and FG of Fig. 24; the vertices of the polygon are then fixed by using the distances in the last two columns as coördinates; A, for instance, being 715.63 feet above FG and 808.87 feet to the right of NS. The minus signs attached to some total latitudes now indicate simply that they lie below FG.

Any other point than F might have been chosen through which to draw the axes. If E had been thus used, all the total latitudes would have been plus, while some total longitudes would have been plus, and some minus.

44. Surveys based on a System of Coördinates. In extended surveys the area is often divided into squares whose sides may be from 50 feet to several hundred feet in length

according to the magnitude of the work. The origin is some prominent point, such as the center of the dome of City Hall, and the sides of the squares run north and south, and east and west.

The corners of at least some of these squares are actually located on the ground, and the computed position of points of a survey in the neighborhood of such a marked corner may be verified by independently locating it from the corner.

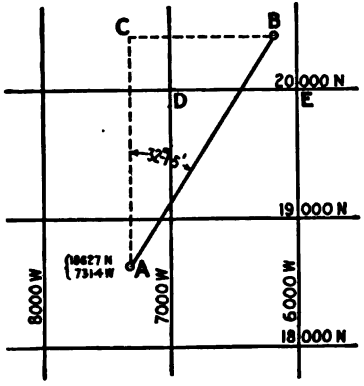


Fig. 25.

In plotting such a survey the points are located from the sides of the squares in which they lie ; thus an error made in locating one point is not carried into the location of the succeeding points, and, as in the method of Art. 43, all the work is done by scaling lineal distances, and does not involve laying down any angles as such.

In Fig. 25 suppose that AB is 2128.3 feet long, that it makes an angle of 32°-15′ with the true meridian, and that the coördinates of A are 18,627 N, and 7314 W. By computing AC and BC and adding them (algebraically) to the coördinates of A, the coördinates of B are found to be 20,426.96 N, and 6178.31 W.

B may now be laid off 426.96 feet above the 20,000-coördinate and 178.31 feet to the left of the 6000-coördinate.

If some corner, as D or E, not far distant from B, be marked on the ground, the surveyor may easily determine the coördinates of B by observations from such a corner and thus check the work above described.

45. Plotting Surface Markings. The locations of trees, shore lines of streams, points on contour lines, etc., do not need to be located with the extreme accuracy which would demand one of the above methods of plotting; and as there are often large numbers of these surface markings to be plotted, a method which is at the same time rapid and reasonably accurate is desirable. These "side shots" are usually made in the field by the stadia method; that is, the transit is set at the forward end of a previously determined line (which may or may not be one of the principal lines of the survey), the angles to the various objects are measured, and their distances from the instrument are determined by means of the stadia "wires" in the telescope. Hence an angle and a distance must be laid off on the drawing to locate the observed points. The problem is not essentially different from some already considered, but the desirability of speed in the operation of plotting leads to different methods, and this usually means the use of a special form of protractor.

The combination of protractor and scale shown in Fig. 26 is the device of Mr. Clifford Foss of Boston and has been in satisfactory use for several years. It is made from a circular paper protractor and a paper scale, the former being cut away so that the scale may be set in with its back flush with the back of the protractor, its zero of graduations at the center of the latter, and its graduated edge coincident with a diameter. The two parts are fastened together by pasting strong thin paper across their junction at the back, and on the front, so far as figures will allow.

In use the instrument is placed with its center at the point from which the "side shots" are to be plotted, and a fine needle is thrust through the center into the drawing board. The whole is now free to rotate about this point, and to repeat the angles measured by the transit which, in the field work, was set at the point on the ground now represented by the position

of the needle. The figure shows the circle graduations numbered for reading azimuths from the rear end of the line upon which the center of the instrument is placed, though they may, of course, be numbered to suit any other method of making the field observations. The whole instrument is rotated till the required circle graduation is brought to the line AB, then the distance to the object is laid off at the edge of the scale.

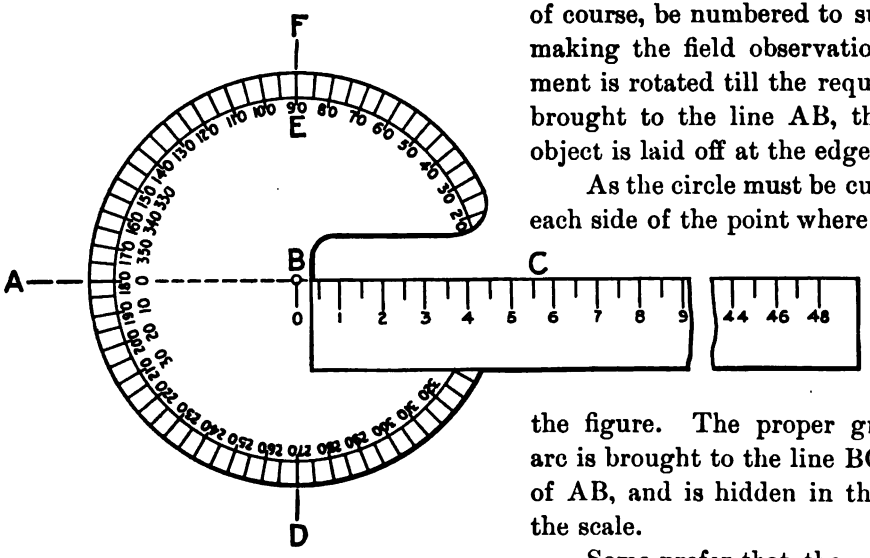


Fig. 26.

As the circle must be cut away for a few degrees each side of the point where zero would otherwise be shown, angles falling within this range are protracted by means of an auxiliary arc shown at the left of the figure. The proper graduation on this short arc is brought to the line BC which is an extension of AB, and is hidden in the figure by the edge of the scale.

Some prefer that the zero of the circle (or the 180 degree mark, as the field method may require) be placed at point E since the protractor readings will then be directly before the eye. In this case a line DF is drawn perpendicular to the survey line AB, and to it are brought the graduations of the protractor. Two or more schemes of numbering may be employed on one

protractor, though usually but one method of field work will be followed, and the protractor will be made to correspond to it.

The leading desirable features of this form of instrument are : first, that the protractor and scale are in one piece ; second (and more important), that practically the whole length of the scale is available. The first-named feature renders it necessary to have several complete instruments with different scales for the lineal measurements.

46. Problems. In most cases where exercises and problems involve the plotting of angles it is advisable to draw the outline on paper of generous dimensions, since the operations of plotting extend considerably beyond the finished boundaries. This paper should be smooth and firm, but not necessarily of a quality required for good inked work. The finished plot may be transferred by pricking (Art. 142) to the final sheet, and the drawing finished.

1. The following problems in finished form may be placed on sheets 11 × 15 inches : —

Length of Course, Feet	Deflection Angle	Method of Plotting
336.0	76° – 35′ *r*	Protractor (Art. 36)
87.5	68° – 10′ *r*	"
60.0	103° – 30′ *l*	Chord (Art. 38)
201.0	102° – 20′ *r*	Tangent (Art. 37)
118.5	47° – 50′ *r*	"
394.0	84° – 00′ *r*	Chord
245.7	84° – 35′ *r*	"

Unless it is known in what direction the courses proceed, it is possible to plot two different figures from notes like the above. In this problem consider the first course as having a bearing of N 68°-15′ E.

(*a*) Make a free-hand sketch of the figure, compute the interior angles, and apply the test given in Art. 40.

(*b*) Plot the figure to a scale of 1 inch = 40 feet, using the methods given in the third column for plotting the angles. The free-hand sketch should show whether in any given case it is better to plot the interior or the deflection angle.

2. Given the following notes for a closed polygon, the azimuths being read from the south : —

Length of Course, Feet	Azimuth
852.6	28° – 30′
769.7	136° – 20′
475.0	234° – 15
249.0	327° – 45′
438.5	253° – 20′

(*a*) Make a free-hand sketch; compute the bearings and interior angles, and write them on the sketch; determine whether the sum of the interior angles is correct.

(*b*) Make a table with the following headings, calculate the total latitudes and longitudes, and use these to plot the figure to a scale of 1 inch = 100 feet (Art. 43). In making the table the course leading from the most westerly vertex should occupy the first line.

Length of Course, Feet	Bearing	Latitude		Longitude		Total Latitude	Total Longitude
		+	−	+	−		

3. On a scale of 1 inch = 200 feet lay down coördinate lines 500 feet apart from 3500 E to 6000 E, both inclusive, and 1000 N to 2500 N, both inclusive.

The coördinates of A, the beginning of course AB, are 1284 N, 3692 E; the course is 1050 feet long and runs N 62°-50′ E. Compute and plot the coördinates of B, and draw AB.

From the following data compute the coördinates for, and plot the three courses succeeding AB: —

BC is 516.5 feet long and makes a deflection angle of 53°-10′ to the right of AB.

CD is 754.0 feet long, with azimuth 240°-30′ from the south.

DE is 630.4 feet long and makes an interior angle of 76°-10′ with CD, the general direction of DE being northwest.

Find also the coördinates for F, the extremity of AF which passes through the intersection of 2000 N and 4000 E, and is 1080 feet long.

Draw FE and find its length and bearing.

A check observation from the intersection of 2000 N and 5000 E shows E to be distant 482.83 feet, with bearing N 40°-35′ E. Compare the coördinates of E calculated from this observation with those previously calculated.

In the above work use the nearest hundredth of a foot in distances, and the nearest ten seconds in arc.

CHAPTER IV

TOPOGRAPHICAL DRAWING IN INK

47. Topographical Symbols in General. The outlines of a map having been drawn by methods already described, the surfaces of the various portions are finished with appropriate symbols and markings. These give relief and variety to the map and convey at once an idea of the physical condition of the surface — first, as to the distribution of land and water; second, as to the various forms of vegetation on the land surfaces (or the character of the ground if no vegetation is present); and third, as to the configuration of the ground. In this last instance the method of indicating relative heights of various portions of the surface is usually by means of contour lines which will be considered in another chapter. These do not give a pictorial effect. It is sometimes desirable to give a definite suggestion of a steep declivity, as a railroad embankment or cut, or a headland, and a special symbol is in use for that purpose.

Fig. 27.

To suggest clearly an idea of the objects represented, symbols are to a certain extent pictorial. They are sometimes represented in elevation and sometimes in plan. Thus the symbol for grass land (Fig. 29) is obviously a tuft of grass shown in elevation, while that

for cultivated land (Fig. 31) is an attempt to suggest furrows in plan. A more general pictorial effect is sought in some cases, as in the representation of fresh marsh. Compare Fig 27, which is from a photograph, with the symbol, Fig. 34; and Fig. 28, which is also from a photograph, with the corresponding method of representation, Fig. 35.

Indeed, these representations are so pictorial in character that the term *symbol* is not very appropriate, but its use has become so common as a convenient term that it is retained here.

From a photograph by Mr. William Lyman Underwood.

Fig. 28.

48. The Sizes and Distribution of Symbols is a matter demanding some attention, but no fixed rules covering all cases can be given. The sizes will vary somewhat with the size and scale of the map, but not in exact proportion therewith. As soon as the draftsman has a clear idea what his finished map should look like he properly adapts his symbols to secure that appearance. The following may be stated as the leading characteristics of a good map so far as the symbols contribute to its appearance: When viewed from the point dictated by its size, scale, and purpose, no portion of the surface should appear more prominent than would the corresponding portion of the actual earth's surface ; the individual symbols must not be so large as to be obtrusive

or to suggest that they were drawn large in order to cover the area more quickly, neither should they be so minute as to seem affected; there must be clearness and a definite purpose in each stroke, so that every portion of the map will bear close inspection.

49. Grass Land, Fig. 29, is indicated by covering the area evenly with the symbol, but without preserving a definite geometrical order in repeating it. At *a* it is shown that the tuft consists of an odd number of strokes, the middle one standing vertical, while the others are curved. The extreme strokes are hardly more than dots. The general outline to be kept in mind is indicated at *b*. In drawing the tuft the strokes may be made in order from left to right or the middle one may be drawn first and the others drawn on either side of it, as the draftsman chooses.

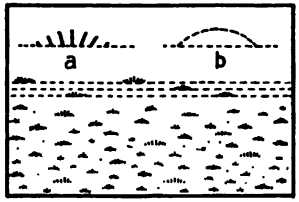


Fig. 29.

It is essential that the bases of the individual tufts shall be on *straight* lines parallel to the lower edge of the drawing, and that there be no suggestion of geometrical arrangement.

If difficulty is experienced in these particulars, aid may be secured by ruling parallel pencil lines considerably nearer together than the required average distance between symbols and by drawing the bases of the symbols to these lines. Whether or not advantage be taken of this assistance, the symbols should be placed at first in a very scattering manner, covering the area with them far apart in all directions, and gradually bringing the whole to the desired appearance by going over the surface several times, each time filling up the most obviously open spaces. It is best on first going over the area to draw the symbols with seven strokes, and in the subsequent filling-in to use a fair sprinkling of five-stroke and three-stroke symbols, the lat-

ter being used where there is only a slight appearance of a blank space. Even single dots may be used at the very last to obtain an appearance of absolutely even tint.

By placing the ruled pencil lines near together the necessity of drawing many symbols on any one line is reduced, and the suggestion of geometrical arrangement is thus avoided. These lines do not need to be exactly equidistant, and so may be ruled quite rapidly.

The expedient of first covering the surface with symbols drawn in a widely scattering manner should be resorted to in all cases where geometrical arrangement is to be avoided.

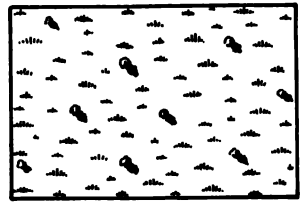


Fig. 30.

50. Cleared Land, Fig. 30, is shown by the symbol for grass with a sprinkling of bushes drawn as for trees, Fig. 33. The grass tufts may be drawn slightly higher in proportion to their width than is the case in showing grass land, thereby indicating a ranker growth.

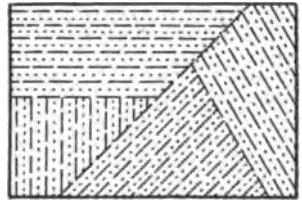


Fig. 31.

51. Cultivated Land, Fig. 31. Here regularity in arrangement is desired. The alternate lines of short dashes and of dots are drawn with a ruling pen against a straight edge. The breaks between dashes should be short and uniform, and while the dashes should be of uniform length, care must be taken that there may not be a series of these breaks opposite each other in adjacent lines, thus suggesting a white line crossing the lines of dashes. The object to be represented here is a series of furrows. Variety is obtained by assuming that the field is broken up into sections, with the furrows running in different directions in adjacent sections.

52. Sand, Gravel, and Mud, Fig. 32. In general, areas covered by sand are represented by fine dots distributed evenly over the surface, but without order. Sand hills or dunes are represented by leaving blank spaces for summits or ridges. When one edge of an area is sharply limited, as by a shore line for instance, the dots are placed in order for some distance back from the limiting line. A row of somewhat heavy dots is first placed close to and parallel with the line, and the dots in the second row are so placed that each one is the vertex of an equilateral triangle, its two nearest neighbors in the first row being the other two vertices. As the work proceeds away from the edge the dots are made finer and the sizes of the triangles are increased, thus giving the appearance of a graded gray tint which grows lighter as it recedes from the defining edge. This work must be done with some deliberation, especially where the dots are arranged in order; even where they are not so arranged the pen must be brought squarely down upon the paper, and must be raised from it without having been pushed along the paper in any direction, in order that a perfectly round dot may be produced.

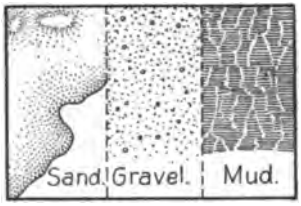


Fig. 32.

Gravel is represented by the symbol for sand, with a mixture of small closed curved figures and a few angular figures representing stones. The dots may be coarser and more irregular in size than in the representation of sand.

Mud is shown by sets of short dashes drawn free-hand parallel to the base of the sheet. The edges of adjacent sets may be separated very slightly, thus giving an appearance of a dark gray color intersected irregularly by fine white lines. The area should first be covered by scattered groups of dashes, and the blank spaces should then be gradually filled.

53. Trees, Fig. 33. The symbol for deciduous trees must be drawn with great care. The usual tendency is to introduce too many strokes in the vain hope of bringing out a picture of a well-rounded tree, whereas, the appearance of light, loose texture, characteristic of trees seen in plan, is desired.

This is the first symbol in which it is necessary to consider illumination. The upper left-hand half of each tree is supposed to be in sunlight. The lower right-hand side will then be in shade, and on that side the shadow of the tree will fall. On the illuminated side mere outlines suggestive of two or three main branches should be shown in fine lines, while on the opposite side the strokes should be heavier and more numerous. The long axis of the elliptical shadow should lie at 45° with a horizontal line, and the free-hand lines of which the shadow is composed must be at right angles to this axis. The draftsman may find it necessary at first to draw the outline of the shadow in pencil. If difficulty is experienced in drawing this sign, it may be traced several times from the figure till the relations and forms of the outlines are learned.

Individual Evergreen Trees are not so commonly represented as are those of the deciduous sort. The white area in the center, shown in Fig. 33, should first be provided for by drawing a circle in pencil from which the spray-like limbs radiate. The shadow, as shown, is tapered to suggest a cone-shaped tree.

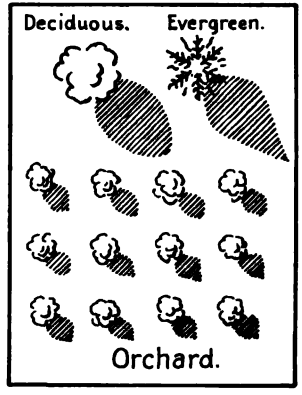


Fig. 33.

54. Foliage in Mass, Fig. 34. In drawing this symbol there is often a tendency to cover the paper too thickly, and to make aimless strokes. The symbol for individual trees

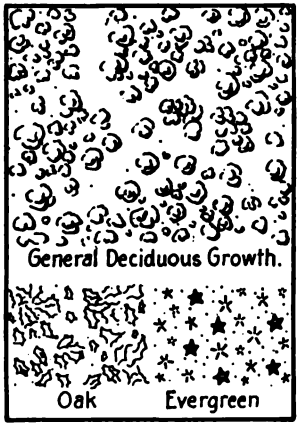


Fig. 34.

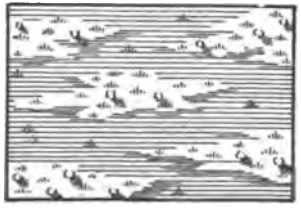


Fig. 35.

is the basis to be kept in mind, but for growth in mass a more sketchy treatment is desirable. The area should not be covered uniformly, but by suggestions of irregular groups of trees. See also Fig. 27.

Fig. 34 also shows a special sign for oak, and two symbols for evergreen, both of which may be used on the same area.

Considerable practice may be needed in this work, especially in showing deciduous growth.

55. Fresh Marsh, Fig. 35. The representation is of irregular patches of ground rising slightly above shallow water, and covered with rank grass. A few tufts of grass in the water itself give the idea of shallowness.

The outlines of the land should first be drawn in pencil, after which the lines representing the water should be ruled parallel to the lower edge of the drawing. These must be rather close together, otherwise they will not serve well to outline the land areas. On the lower side of each island short interlinings are drawn free-hand and very fine. They suggest a reflection of the island, and therefore give an appearance of relief; they also serve to outline the indentations of the islands more accurately than would otherwise be possible. The tufts of grass and a few small bushes complete the representation.

56. Salt Marsh, Fig. 36. The ruled lines may be farther apart than in the symbol for fresh marsh, since there are no islands to be defined.

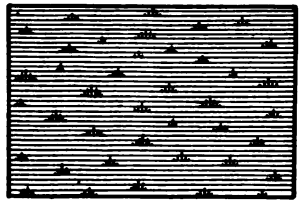


Fig. 36.

57. Water, Fig. 37. No feature of a topographical plan adds more to its good appearance than the skillful representation of a body of water.

The shore line is first drawn, free-hand, as a firm heavy line. A coarse pen should be used so that no pressure will be required to produce a line of the required weight. The first "water line" is then drawn as close to the shore line as the skill of the draftsman permits. The eye should be kept on the *spaces between the lines* rather than on the lines themselves. Successive water lines are then drawn at constantly increasing distances. As the work progresses, the lines are made finer by the use of successively finer pens.

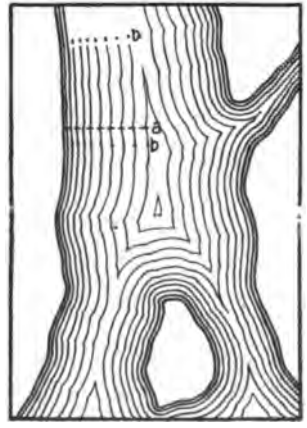


Fig. 37.

Three Essentials are to be noted : —

First, the water lines must be wavy in form, this effect being secured by making the lines a succession of curves concave toward the shore. The indentations of the shore will often dictate the points where two such curved lines join, but the curved form must be maintained even where a long smooth stretch of shore line occurs. In every instance the wavy form must be worked in very

gradually, the first two or three lines following the shore line without a hint of wave except as the form of the shore may incidentally produce it. The junctions of curves are convenient points for lifting the pen and changing the position of the hand; but there must be no indication that the line was stopped at such a point, neither should there be a slight open space between the ends of the lines, nor a crossing of the ends, nor a thickening of the line at the junction.

Second, the points at which the curves join must not be chosen at random, but must be opposite each other in successive water lines. To insure this arrangement pencil lines should be drawn normal to the shore line at *each* place where a row of these junction points will occur, as at *a*, Fig. 37. This pencil guide-line is especially useful in the long stretches where there are no indentations in the shore line.

Third, two adjacent water lines must be *equidistant* throughout their extent. As a step toward this end, at the same time providing for spacing the lines at successively greater distances, a row of dots should be drawn normal to the shore line, as at *b*, the distance between them being gradually increased as they recede from the shore line. The edge of a piece of paper may now be placed alongside the dots, and their relative positions copied on the strip. This should then be placed at intervals normal to the shore line, and the positions of the dots copied on the drawing, where they will serve as a gauge for properly spacing the water lines.

Having begun any given water line it must be finished before another is commenced. The paper should be shifted frequently (or the body shifted relative to the drawing, if the latter is large) so that the hand and arm will not be in a cramped position as the lines are drawn. In general draftsmen draw most steadily when the strokes are made downward toward the body.

If the body of water is small, the water lining may cover the entire area; if it is quite large, only a few lines at the edge need be drawn.

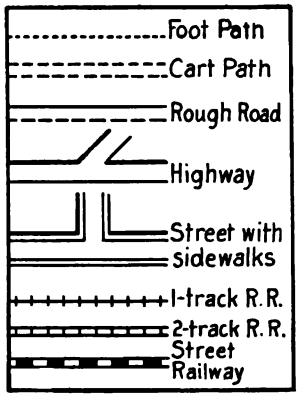


Fig. 38.

58. Roads and Streets, Fig. 38. The method of drawing highways and streets with sidewalks apparently violates the general rule for the use of shade lines, since these are shown at the left-hand and upper street lines. The assumption is that the land at the sides of the streets is at a higher elevation than the road bed, and the various parcels of land are the objects whose boundaries are considered relative to shading; hence the heavy lines should be considered as the right-hand and lower sides of the lots of land adjacent to the streets.

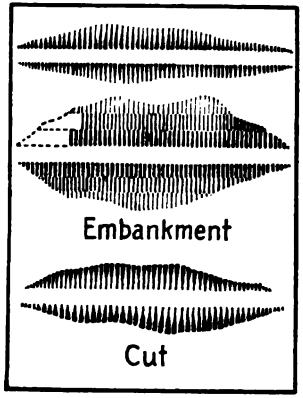


Fig. 39.

59. Railways also are shown in Fig. 38, and need no comment.

60. Embankments and Cuts, Fig. 39. Steep declivities, such as occur on headlands eroded by the action of water, or such as are formed artificially at railway embankments and cuts, are indicated by series of tapered lines or "hachures." The flat top of an embankment, or the bottom of a cut, is shown by a blank area of the appropriate width between the series of tapered lines.

In the embankment the thick ends of the hachures are at the flat top of the embankment, while in the cut the thin ends are at

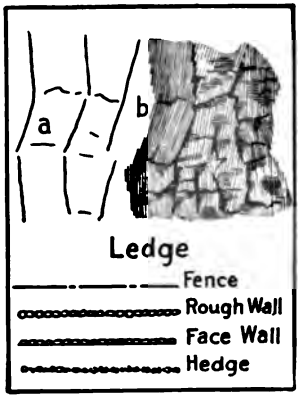


Fig. 40.

the flat bottom; that is, in each case the thin ends point down the slope.

The slopes are represented by single strokes with a fine, flexible pen (such as Gillott's mapping pen) when the area to be covered is not too wide to accommodate a free movement of the fingers. A skilled draftsman practiced in this work will draw hachures an inch long with single, quick strokes; in general, however, if the area is more than three eighths to one half inch wide, it is necessary to proceed as shown in the second representation of embankment, Fig. 39. (The same method is applicable to representing a cut.) The area is divided into longitudinal strips, each of which is filled with hachures which do not taper; but which, in successive strips, are graded as to weight and spacing, so that the result resembles that of single long strokes.

61. Ledge, Fig. 40. The area to be covered should first be roughly blocked out in pencil, as shown at *a*. Each small area thus formed should then be covered by a series of very fine parallel lines, drawn free-hand, as shown at *b*. Seams and crevices are then worked in.

62. Fence, Wall, and Hedge. Fig. 40 shows also the signs used for these features.

Fig. 41.

63. Buildings. In some cases it is not a matter of interest to show the material of which buildings are constructed; in this case they are drawn either as shown for wood or for stone, Fig. 41. If it is desired to indicate the material the method shown in the figure may be used.

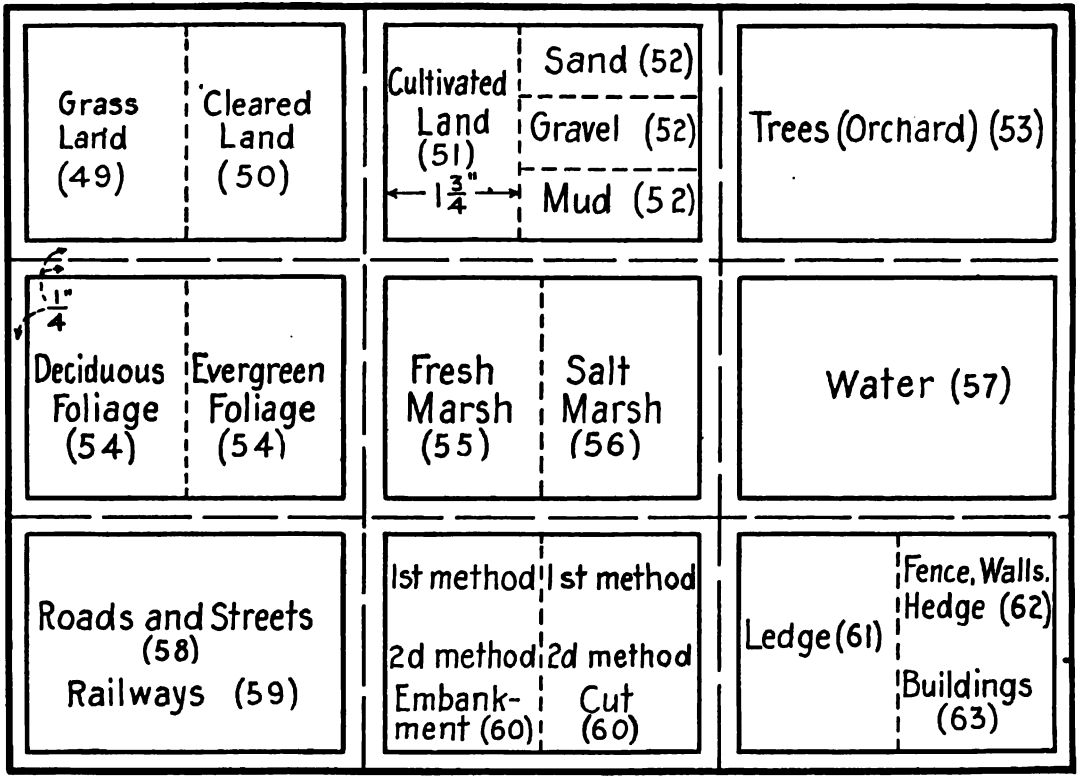

Grass Land (49)
Cleared Land (50)
Cultivated Land (51)
1 3/4"
Sand (52)
Gravel (52)
Mud (52)
Trees (Orchard) (53)
1"
4
Deciduous Foliage (54)
Evergreen Foliage (54)
Fresh Marsh (55)
Salt Marsh (56)
Water (57)
Roads and Streets (58)
Railways (59)
1st method
2d method
Embank-ment (60)
1st method
2d method
Cut (60)
Ledge (61)
Fence, Walls, Hedge (62)
Buildings (63)

Plate I.

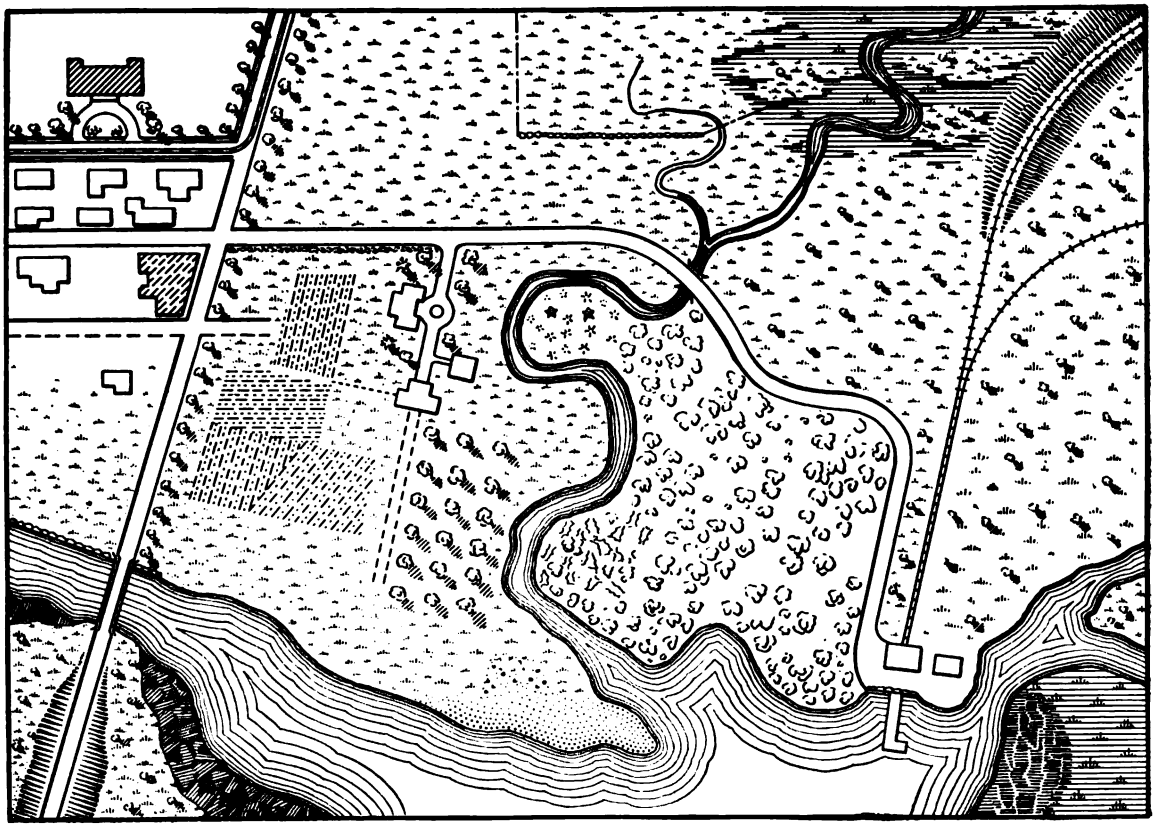


Plate II.

UNIV OF MICH

64. Exercises. 1. Plate I shows the lay-out of a sheet with border line 10 × 14 inches, for practice in making the various topographical signs. The sheet is first divided into nine equal rectangles as shown by the broken lines. Each rectangle is then furnished with a border line $\frac{1}{4}$ inch from its edges, and is filled with the sign or signs indicated. The figures in parentheses refer to the sections which describe the various signs.

For this work paper with a smooth, hard surface is best, such as linen record paper, or Bristol or Strathmore board ; tracing cloth is also suitable.

It frequently happens that some symbols will not be satisfactorily executed, and a student's time will not permit that the whole sheet be repeated till all portions are satisfactory. It is suggested that the nine rectangles be considered separately, and that they be cut out on the broken lines. Any one of these may then be repeated without sacrificing the others, and when all are completed, they may be kept as separate cards or mounted in order on a large sheet.

2. Plate II shows the topographical symbols used in a map. This may be enlarged to 10 × 14 inches by any method explained in Chapter VIII, and drawn as an exercise in the use of symbols.

CHAPTER V

TOPOGRAPHICAL DRAWING IN COLORS

65. Preparation of the Color. One of the cabinet saucers is first filled about half full from the water glass. A clean brush dipped in clean water is then pressed against the rim of the glass to remove a considerable portion of the water which it will have taken up. The brush is then dabbled first in the pan of color, then in the saucer of water, and so continued until the water has acquired the required depth of color, which is determined by applying a brushful to a bit of paper of the same kind as that on which the color is to be used.

With light, transparent colors, such as gamboge, this is the end of the process; with heavy colors, such as burnt sienna, the preparation must be allowed to stand quietly for a few moments to settle. It is then quickly poured into another saucer, care being taken that the settlings be retained in the first saucer.

66. The Nature of a Tint. The color prepared as directed above should not be regarded as *paint*, a coating of which is to be spread thickly over the paper, but rather as water slightly colored, a thin film of which is to be evenly and lightly applied. If the paper could be dipped into this water and held up by one edge so that all surplus water would run off, the proper effect of tinted paper would be secured. But as this is not practicable in making drawings, a brush is used to spread the color over the desired areas. Water colors are more

or less transparent when thinly applied, and the white of the paper beneath the color modifies it so that what might otherwise be a crude glaring effect is toned to a pleasing tint.

67. Applying the Color. The board upon which the paper has been stretched (Art. 29) should be raised at its back edge so that the surface will slope downward toward the draftsman, making an angle of about 20° with the horizontal.

With the brush charged with color, but not filled as full as it will hold, begin at the upper left-hand corner of the area to be colored, and draw a band from left to right as broad as the brush will lay smoothly. Cause the point of the brush to travel along the upper boundary so that it will not be necessary to go over the ground again. The surplus color will at once run to the lower edge of the band. Having worked the tint exactly up to the right-hand boundary, draw another band from right to left joining the first one. The surplus color will all run to the bottom of the second band, and if the work is done quickly, so that the lower edge of the first band has not begun to dry, the two bands will be perfectly blended together into a single broad one. This process is repeated till the whole area is covered, when the remaining surplus color is taken up with blotting paper, or with the brush dried by touching it to blotting paper. When dry, the color should be perfectly "flat," that is, of uniform depth, without spots or streaks.

In general the desired tint is secured by a single wash of color, but some colors, such as Prussian blue, are difficult to lay flat, and it is better to lay two weak washes, giving the first ample time to dry before the second is applied.

The following general directions must be followed to attain success : —

1. The brush must not be regarded as a pen or pencil whose point only is to be used ; on

the contrary it is an instrument for spreading the color in broad areas, and to this end it is pressed against the paper so that practically the whole side is in contact with it.

2. The brush must be filled often, but never so full as it will carry.

3. The work must progress so rapidly that no band of color will have dried, or even "set" at its lower edge before the next one is joined to it. In fact the brush must be considerably in advance of the nearest point where the color has dried, otherwise streaks and blotches will result.

Speed is not gained by hurried nervous strokes. The sweep of the brush may be deliberate, even slow, but it must cover a wide band, and cover it thoroughly, so that it will not be necessary to go back to touch up blank spots. The wash must also be carried fully out to the boundaries as the work progresses. It is fatal to go over the surface the second time when the first wash has made the least beginning at drying, except as described above for two coats over the entire area.

4. Paper suited to the work must be used. (See Art. 17.)

5. Perfect cleanliness and neatness must be observed. Preliminary penciling should be carefully done so as to avoid the necessity of making erasures. If erasures are necessary, they should be made with a very soft rubber, for if the surface of the paper be roughened, the color will settle in a darker tint than appears where no erasures have been made.

A piece of clean cloth or paper should be placed between the hand and the drawing during all stages of the work, to protect the drawing from perspiration, otherwise the color will not be flat. If from this or any other cause the paper is greasy, it should be rubbed lightly with chalk dust applied with a soft cloth or chamois skin. The chalk must be thoroughly removed, however, before any color is laid on. A little ox gall in the color will cause it to be

worked more evenly on a slightly greasy surface. The point to be attained is to keep the drawing so clean that none of these expedients will be necessary.

A brush charged with one color must be cleaned before touching it to another, for each color should be kept free from dust, dirt, and stains of other colors.

As soon as practicable after using a brush it should be rinsed thoroughly in clean water, special care being taken to get all color out of the heel, by pressing it repeatedly against the bottom or side of the glass. It is better not to touch the hairs of the brush with the fingers. When the cleaning is finished, hold the brush by the end of the handle and shake it quickly so that the water will fly out. This should leave the brush end straight and nicely pointed, as it should always be before it is put away.

6. The color in the saucer should frequently be stirred with the brush to keep the tint uniform.

When large areas are to be colored, the paper should be slightly, but thoroughly and evenly, moistened with a large brush or soft sponge. If the color is then applied before the paper is thoroughly dry, a tint can be laid much more rapidly and evenly than upon dry paper. When there is much moisture in the atmosphere, the paper will absorb enough to make a noticeable difference in its readiness to take color.

68. Inking. It is better to defer the inking of the drawing until after the coloring is finished. This is sometimes inconvenient, especially when there is but little coloring as compared with the amount of lining. If the inking is done first, it must be done with waterproof ink. The main reasons for doing the lining last are: first, uniformity of tint is more easily secured; and second, the drawing will look more brilliant and clean cut, since the uniform

blackness of the lines will not be injured by being partly covered in places by the color, as would otherwise be the case. There is a repellent quality in many waterproof inks that results in the color being driven away from the line, so that a narrow band of the tinted area adjacent to each inked line is slightly lighter than the rest.

69. Making Corrections. If for any cause portions of a tinted area are darker than others, the surplus color may be removed by going over the area with a brush charged with clean water, and immediately applying a piece of clean blotting paper. The operation may need several repetitions. Another method, usually more satisfactory, is to rub the dark areas gently with a rather soft eraser.

A light area may be deepened in tone by **stippling**, a process which consists in covering the area with small dots of color applied with the point of a small brush or with a pen. The color should be the same as that used for the wash, and individual dots should not appear as such, except upon very close inspection.

70. Laying a Graded Tint. It is difficult to show by a printed figure, either in black or in color, the effect of a uniformly varying tint. Fig. 42 is given as an attempt to indicate this effect. However, the following directions should be sufficient to enable one to lay a graded tint successfully. Exercises in covering rectangular outlines with such a tint look best with the dark portion at the top, as shown, but the process should be that of working from light to dark, the board being turned so that the edge which is to be light is at the top.

Provide two saucers, in one of which is an ample quantity of the color to be used, mixed considerably darker than is desired for the dark edge of the area to be colored; in the other should be a small quantity of clear water or of weak tint, according to whether the light edge

of the rectangle is to be colorless or to have a slight color. With the brush charged with only a small quantity of the water or weak color draw a band across the top of the rectangle. Then take up with the brush a small quantity of the strong color, mix it quickly but thoroughly with the contents of the saucer first used, and apply a second band of this slightly deepened color immediately below and touching the first band, which must not have been allowed to dry before the second band is applied. The two bands will blend together. Again add some of the strong color to the weak, and draw the third band, blending it with the second.

Fig. 42.

The two important points to be observed are: first, the amount of color in the brush when a band is drawn must not be so great that any considerable amount of excess liquid will run to the lower edge of the band, otherwise it will not blend well with the succeeding band; second, a regularly increasing quantity of the stronger color must be added to the weaker. The additions are in a sort of geometrical proportion, as the amount of liquid as well as the depth of color is ever increasing in the saucer to which the strong color is added.

71. Blending. The effect of a blended edge of a band of color is the same as that of a graded tint; that is, the color gradually fades away into the white of the paper. But the method employed confines the width of the area in which this grading takes place to a single brush stroke.

For this work a double-end brush is most convenient, one end being filled with the color to be used, the other with water. Having drawn the band of color, the water brush is then passed along the edge to be blended, sufficient pressure being applied to spread the brush considerably. Its edge should just touch the color, which will then run into the water band and thus become blended. The whole operation must be finished quickly, before the edge of the color band can "set." In drawing the water band care must be taken that the whole of the paper in the width covered shall be wet, and that every point in the edge of the color is touched. Only one passage of the water brush should be made, and any attempt to remedy defective spots before the whole work is dry is sure to be unsuccessful.

It is important that neither brush be very fully charged. As in laying a graded tint, the color band must not have a puddle at its lower edge, and if the water brush is too heavily charged, the water band will run into the color, whereas the color should blend into the water.

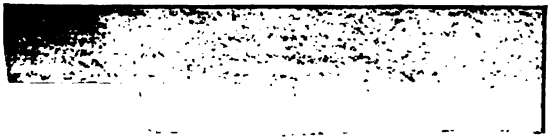


Fig. 43.

If the band is more than about 3 inches long, as is frequently the case in shore lines, for instance, the blending must be started before the color band is finished. As shown in Fig. 43, about 3 inches of the color band is drawn, then all but about $\frac{1}{2}$ inch of this is blended. The color and water bands are thus alternately applied, the latter always being stopped short of the end of the former till the last section of the work is reached.

72. Mottling, Fig. 44. Mottling consists in introducing spots and streaks of one color into a groundwork of another color, the two being blended together. The purpose is to re-

lieve the monotony of a large area of the ground color, and also to serve as a topographical sign. (See Art. 79.)

The two colors should be of equal strength, so that the spots will not stand out aggressively; and, as in all operations involving blending, the brushes must be about equally, and not excessively, charged with the colors.

Having laid a portion of the ground color, put on an irregular spot or streak of the other color, its upper edge being brushed in contact with the lower edge of the ground color, where blending will at once take place; then resuming the ground-color brush, draw around the spot, always touching its edge, and continue the ground color till it is desired to introduce another spot. At the lower edge of the figure is shown a spot as it is brushed on, and before the ground color is brushed around it.

Fig. 44.

Though all this work must be done rapidly, so that no edge will dry till the whole is finished, it must be remembered that in this, as in most operations in coloring, rapidity is secured by using a good sized brush, by putting sufficient pressure upon it to spread it well, and by covering the paper completely the first time the brush is passed over it.

73. Dragging, Fig. 45. In this operation the color is applied in ragged, cloudlike patches. Dragging is used in the representation of salt marsh (Art. 86) and of rocky surfaces (Art. 91).

The brush must contain but very little color. After having dipped it into the color saucer it should be drawn across the edge of the latter to discharge most of the liquid, and it may sometimes be necessary to further discharge it by pressing the brush flatwise upon blotting paper. If the brush has a ragged edge upon leaving the blotting paper, so much the better. Much depends upon the shape of the brush and the amount of color it contains.

Fig. 45.

The brush is held nearly flat upon the paper, and moved always parallel with the lower edge of the drawing, with the handle in a vertical plane perpendicular to the direction of motion. The pressure upon the paper should be uneven, so that varying portions of the brush will be in contact from moment to moment.

74. Matching a Color. It is often necessary to prepare a color which shall be exactly like one already applied to a drawing. This often proves surprisingly difficult to do, as the presence of other colors on the drawing deceives the eye as to the quality and intensity of the color in question.

To eliminate these effects take a piece of paper like that on which the drawing is made, cut a hole in it at a considerable distance from the edge, and apply a wash of the trial color around the hole, and to a considerable distance from it. When this color is dry, lay the paper over the drawing so that the color to be matched will show through the hole. Any differ-

ences between the two washes will then be clearly apparent, and other trials are made in the same manner till no difference appears.

75. Combinations of Colors. While pigments for water coloring are made in great variety, it is necessary, in technical drawing, to have only a few of these, the remaining necessary ones being obtained by combinations.

The pigments needed for the present purpose are mentioned in Art. 22, and the initials of their names as there given will be used in the following pages.

Starting with the primary colors red, blue, and yellow, the secondary and tertiary colors may be derived as shown : —

Primaries	Secondaries	Tertiaries
Red	Violet = Red + Blue	Russet = Violet + Orange
Blue	Green = Blue + Yellow	Citrine = Orange + Green
Yellow	Orange = Red + Yellow	Olive = Violet + Green

The secondaries are produced by a combination of the proper primaries in almost any proportion ; thus the addition of very little yellow to blue will produce green, and upon successive additions of yellow the combination still remains green, though it may pass through all the shades from "bluish green" to "yellowish green." The tertiaries are not so easily prepared. Russet, for instance, is a mixture of violet and orange, the violet being a combination of red and blue, and the orange a combination of red and yellow. Thus in the composition of russet the primary red enters twice and the primary blue and yellow once each. Citrine and olive

are, in a similar way, found to consist of varying proportions of the three primaries, and the relation of tertiaries to primaries may be shown as follows: —

Russet = 2 red + blue + yellow
Citrine = 2 yellow + red + blue
Olive = 2 blue + red + yellow

The above is not intended as a guide by which to mix the tertiary colors. Considerable experimenting is usually necessary to obtain the tertiaries, since a combination of the three primaries produces neutral tint except when they are in exactly the correct proportions to produce the tertiaries.

76. Special Combinations of Colors. Colors for special purposes, or for greater variety than those given in the last article, may be produced as shown below: —

Azure, cobalt + white
Buff, yellow ochre + white + red
Chestnut, red + black + yellow
Chocolate, raw umber + red + black
Claret, red + umber + black
Copper, red + yellow + black
Cream, burnt sienna $\frac{1}{4}$ + yellow $\frac{1}{4}$ + white $\frac{1}{2}$
Dove, vermilion + white + blue + yellow
Drab, yellow ochre + white + red + black
Flesh, yellow ochre $\frac{1}{4}$ + vermilion $\frac{1}{4}$ + white $\frac{1}{2}$
Lemon, chrome yellow + white
Olive, yellow + blue + black + white

Peach, vermilion + white
Pink, rose lake + white
Rose, madder lake + white
Violet, blue + red + white

Greens

Bronze, chrome green + black + yellow
Dark, Prussian blue + chrome yellow
Olive, lemon yellow + chrome green + burnt sienna
Pea, chrome green + white.

Grays

Black + white
Black + white + blue
Burnt sienna + blue + white
Burnt umber + blue
Payne's gray + crimson lake.

77. Topographical Drawing in Colors. In color topography the objects are in some cases suggested by both form and color, as in trees and buildings, and sometimes by color only, as in grass land. The **advantages** derived from using colors are that a map is produced which is more pleasing to the eye, more easily read, and in general, more quickly made than when the symbols are rendered in lines only. The chief **disadvantage** is that a map in colors cannot be cheaply and readily reproduced, either by lithography or blue printing.

As in pen topography the size of symbols will be varied to suit the scale of the drawing.

78. Grass Land is shown by a flat tint of green. P.B. + G. + Y.O. is suitable for this purpose. In meadow land where clover may be supposed to grow, spots of C.L. may be introduced by the method explained in Art. 72.

79. Cleared Land, Plate III, is shown by a flat ground color of green as for grass land, with a mottling of B.S. as explained in Art. 72.

80. Cultivated Land, Plate III. A flat ground tint of B.S. is first laid on, and over this are ruled lines of the same color, but mixed considerably stronger. For variety P.G. + a very little C.L. may also be used for some fields.

81. Sand and Gravel, Plate III. For sand a flat tint of Y.O. is used, and gravel is indicated by dots of B.S. put on with the tip of a small brush or with a coarse pen.

82. Mud is shown by groups of short horizontal lines as in plain topographical drawing (Art. 52), except that a rather heavy tint of S. is used in the ruling pen instead of India ink. A wash of S. should first be laid over the whole area just strong enough to dim the whiteness of the paper.

83. Individual Trees, Plate III, should first be plainly outlined in pencil, after which a bright, and decidedly yellowish green composed of P.B. and G. is laid over the whole area. The lower right-hand half of each tree is then colored with a much stronger bluish green. This should be applied with a rather dry brush, and, along the edge which lies in the diameter of the tree, the touch should be very light and with the tip of the brush, so there will be spots here and there not covered by the color. That is, the effect along this line should be that of "dragging" on a very small scale. The object is to avoid too sudden a transition

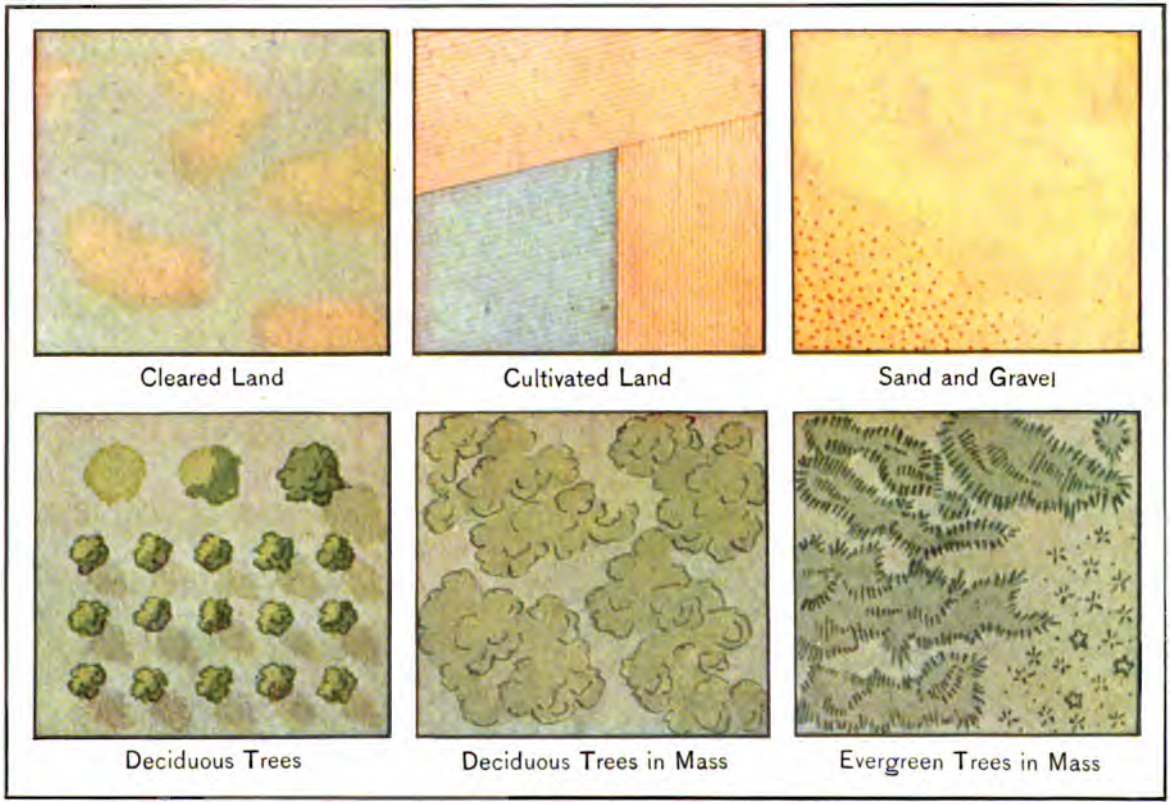

Cleared Land
Cultivated Land
Sand and Gravel
Deciduous Trees
Deciduous Trees in Mass
Evergreen Trees in Mass

Plate III.

from the bright, illuminated side to the side which is in shade. Next the shadow, composed of P.G. + C.L., is brushed in. If this tint is allowed to encroach a little upon the shaded side of the tree itself, the effect of relief will be heightened. Last of all the curvilinear lines are drawn, suggesting the rounded outlines. The color should be very bright and strong, and may be applied with a pen as are the black lines shown in Fig. 33.

Evergreen Trees may be shown as in Figs. 33 and 34, using bluish green instead of ink.

The ground color for grass land, cleared land, etc., is to be put on before the trees are drawn.

84. Trees in Mass, Plate III. For **deciduous trees** patches of green are applied which are irregular in shape and size. This color should be of medium strength, composed of P.B. + G., with a little S. added to deaden the brightness. The curvilinear lines are of the same color, but considerably stronger, applied with the tip of a small brush or with a coarse pen.

Evergreen Trees are shown by the same method except that the final lines instead of being curvilinear, are straight, suggesting the needlelike foliage of pine, spruce, etc. When the scale of the map is small, it may be more effective to use the convention for individual trees sprinkled over the area as suggested in the figure.

85. Fresh Marsh, Plate IV. See also Figs. 27 and 35. The irregular patches of land are rather strongly outlined in pencil, and colored for grass land or cleared land as the case may require. The water surface is then colored P.B. The islands are next given a stronger outline and an appearance of relief by adding lines of a brighter green at their upper edges and shadow lines at their lower edges. These latter lines may be of S. or of I. + B.S. Small trees or bushes may be indicated to heighten the effect.

Care should be taken that the long stretches in the outlines are nearly parallel to the lower edge of the drawing.

86. Salt Marsh, Plate IV. The whole area is first treated with the appropriate ground color, after which P.B. is dragged (Art. 73) to represent irregular patches of water. Lines of stronger P.B. are then ruled along the upper edges of these patches, and always parallel to the lower edge of the drawing. The direction of movement of the brush in dragging must also be in this direction.

87. Water, Plate IV. The method of representing water depends upon the taste of the draftsman and upon the time which may be spent upon the map. A very delicate effect may be obtained by the method of **water lines** explained in Art. 57, P.B. being used instead of ink. The objection to this method is the great amount of time required.

A quick, easy, and often a satisfactory method is that shown at the right of the Plate, where a **flat tint** of P.B. is laid over the water surfaces. The shore line is defined, and relief secured by drawing a narrow band of S. and blending it (Art. 71) toward the land.

A more pleasing effect, and one not requiring an excessive amount of time, is shown in the lower left-hand corner of the Plate, where a **graded tint** of P.B. is laid from the shore lines. The method of grading explained in Art. 70 is not practicable for this work.

The whole width of the body of water is first covered with a flat tint of very weak P.B. A wide band of a stronger tint is then laid next the shore line and blended (Art. 71) on the edge remote from the shore line. When the whole body has received this blended band, another is laid in the same way, but narrower and in a still stronger tint. This process is repeated as many times as necessary to secure the desired effect. Finally a narrow line of a decidedly

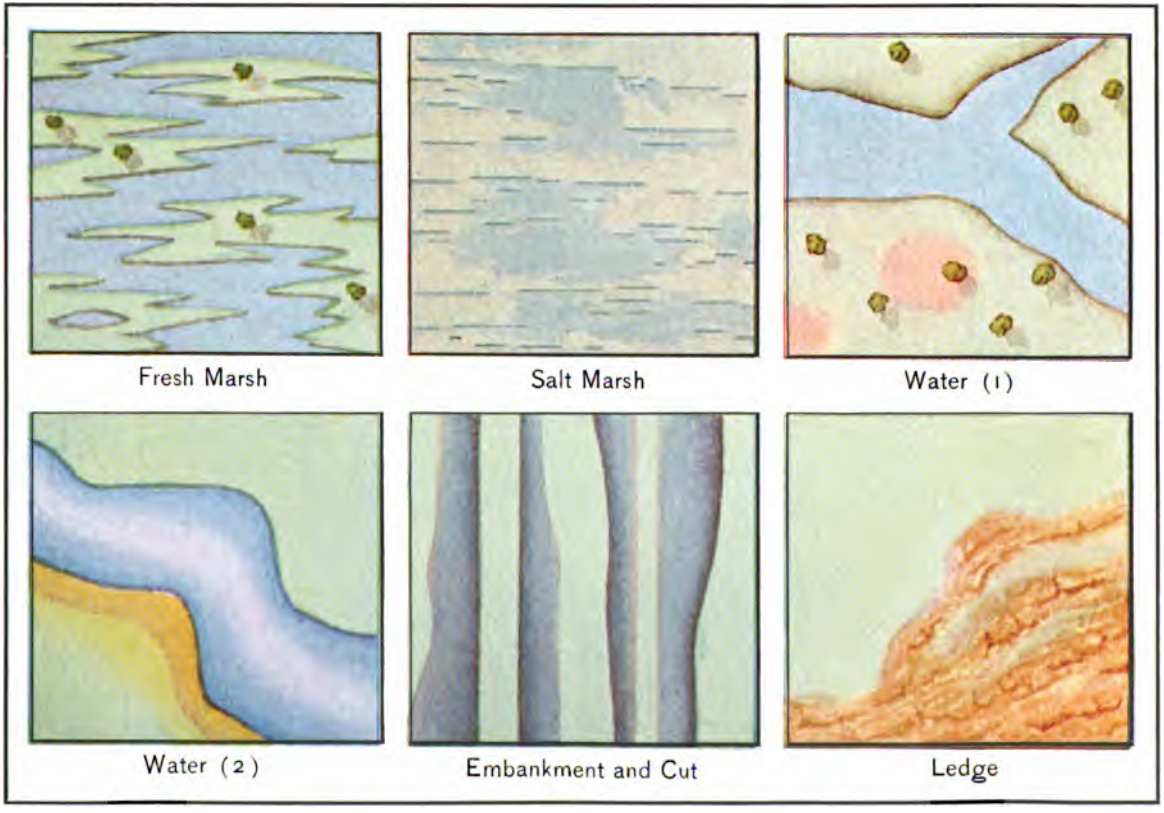


Plate IV.

UNIV. OF MICH.

strong tint is drawn at the shore line with a fine brush or a ruling pen. The shore line may be finished, however, with the blended line of S. as explained for the flat-tint method.

For rather rough work, such as field sheets or preliminary plots, water is often shown by successively narrower and stronger bands of color as described above, but without blended edges.

88. Streets and Roads are colored with a flat tint of Y.O., the edge being defined by inked lines as in plain drawing, Art. 58.

89. Railways are shown as in plain drawing, Art. 59.

90. Embankments and Cuts, Plate IV. The sloping surfaces are expressed by a graded tint of P.G. + C.L. laid by the blending process as explained in Art. 87. As in pen drawing the dark portion of the shaded surface is that nearer the eye ; that is, the dark edge is at the top of the embankment and at the outer edge of the cut. The top of the embankment and the bottom of the cut will be colored to express the actual conditions of these surfaces.

91. Ledge, or Rocky Surface. A fairly strong tint of S. + a little B.S. is dragged over the surface to be covered, the brush being moved along the outcrops in rocky surfaces, or along the supposed lines of continuous rock in ledges. The dragging should be so lightly done that two or three applications of the color will be required. Finally the seams and fissures are drawn with the tip of the brush, in a somewhat stronger tint.

92. Fences, Walls, and Hedges. Fences and walls are drawn in ink as in plain drawing, Fig. 40, but the outlines of the walls are filled in with P.G. A **hedge** is shown as a close row of small trees (Art. 83), a line of shadow being added.

93. Buildings. The outlines are drawn in India ink, shade lines being used. For **wooden** buildings the area within the outline is colored S., **brick** C.L., and **stone** is indicated by P.G.

94. Use of Colored Pencils. While colored pencils (Art. 23) do not give the variety or delicacy of coloring that can be secured with water colors, they are of great convenience, and in some cases their use is to be preferred to that of water colors. For instance, it may be desired to color an area when it is known that at some future time the color will need to be changed; pencil may then be used to advantage, since it can be removed with comparative ease with a rubber eraser.

A city map may have the streets colored to show the various kinds of pavements in use, as red to indicate brick, and brown to indicate asphalt. But some brick pavements may be replaced by asphalt, in which case it is desirable to be able to change the coloring easily. Or a city may have both the "combined" and the "separate" systems of sewerage, the area covered by the former being colored green, and that covered by the latter, buff. But if the separate system is replacing the combined, it is easy to keep the record map up to date if colored pencils are used, thus making erasures easy.

When only a very little coloring is necessary as a given piece of work progresses, pencils are much more convenient, as they are always ready for use, and require almost no room as compared with the articles necessary for water coloring. It is impossible to enumerate, even approximately, the cases where colored pencils may appropriately be used instead of water colors. Each means of coloring has its own sphere, and it should not be supposed that either can wholly replace the other.

95. Use of the Stump. When large areas are colored with pencils, it is desirable to smooth the color with a stump, and this is necessary with small areas also if the best result is to be obtained.

The best stump consists of a tight roll of chamois skin, the ends of which are cut pointed. An inferior stump may be extemporized by rolling up a strip of newspaper or blotting paper, and holding it together by a rubber band. The end is then pared to a point with a sharp knife.

The pencil is first rubbed lightly over the surface to be colored, covering it uniformly, but leaving it slightly lighter in tone than is finally desired. The surface is then rubbed with the end of the stump, which distributes the color evenly, and also rubs it into the minute depressions of the paper, which are not reached by the pencil, thus deepening the tone.

96. Colored Pencils with Tracing Paper and Tracing Cloth. Sketch maps, architectural details, and a great variety of other subjects are often drawn upon tracing paper or cloth, after which the more prominent features are brought out with colored pencils. In such cases, however, the color is best applied on the back of the drawing, for the following reasons: the translucency of the paper softens the cruder colors; though the color is laid on quite roughly, it still looks smooth when viewed from the face of the drawing; the inked outlines are not interfered with, and if any of them need to be changed, the erasures do not disturb the color.

If tracing cloth is to be colored with pencils the drawing should be made on the bright side, leaving the dull, rough back to receive the color.

An advantage in favor of pencils for coloring upon thin paper or cloth is that they do not cause buckling or wrinkling as water colors do.

97. Colors in relation to Blueprinting. If blueprints are to be made from drawings on cloth or thin paper, it is well to avoid the use of blue color, or of secondary colors in which blue predominates, as these colors are transparent to the chemical rays by which the printing is done. Of course it is desirable to use blue for water, but it should be laid on very heavily, and it will always be more prominent on the drawing than its effect will be on the print.

On the other hand, yellow, orange, and red print well, and yellowish green and reddish violet print fairly well.

98. Colored Whiteprints. A common, and very satisfactory method of securing several copies of a colored drawing is to make the outlines upon tracing cloth, from which prints are taken showing either black lines on a white ground or blue on white (Art. 138). These are then colored as desired, either with water colors or with pencils.

If the drawings are to be used frequently, they should be mounted on cloth (Art. 30) after being colored, and this should always be done if water colors have been used, as the surface will otherwise remain more or less wrinkled. If the mounting is carefully done, the coloring need not be injured by the process.

Prints showing black lines on a white ground often prove disappointing when mounted, as the paste used in the work may gradually turn the paper a dirty pinkish color which is likely to have an undesirable effect upon colors previously applied.

Exercises in Water Coloring

99. General Directions. The following exercises are to be performed on Whatman's cold-pressed paper (Art. 17) stretched upon the drawing board (Art. 29). The sheets will be 11×15 inches, with border line 10×14 inches.

It is desirable to stretch a sheet large enough to make two or more of the finished sheets. Atlas paper, 26 × 34 inches, will make four of the small sheets with only as much waste at the margins as is desirable for stretching and for trying the colors.

100. Exercise in Flat Tints. Divide a sheet into six rectangles such that there shall be one half inch between adjacent rectangles, and between each rectangle and the border line.

Color the three upper rectangles with primary colors in this order: 1, G.; 2, C.L.; 3, P.B. The student must remember that the tints are to be kept light, also that it is easier to lay a flat tint if it is light than if it is heavy. Of the three colors named above the P.B. is most liable to give trouble, and the student is advised to apply two very light washes rather than a single one of the required strength.

Color the three lower rectangles with secondary colors in this order: 4, Violet (C.L. + P.B.); 5, Green (G. + P.B.); 6, Orange (G. + C.L.).

Note that each secondary color is composed of those primaries which are *not* above it, and that it "harmonizes" with that primary which *is* above it.

101. Exercise in Graded Tints and in Mottling. Divide a sheet as for the last exercise.

In the three upper rectangles lay graded tints (Art. 70) of the following colors in order: 1, P.G.; 2, Y.O.; 3, S.

The lower rectangles are to be colored as follows, in order: 4, Green mottled (Art. 72) with C.L.; 5, B.S. mottled with P.G. with a very little C.L. added; 6, Orange mottled with Violet.

102. Exercise in Conventional Tints and Symbols. Divide a sheet as shown for Plate I, Art. 64. Taking the nine rectangles in order from left to right, show in them the follow-

ing, the numbers in parentheses referring to the articles which should be read carefully (in addition to a study of Plates III and IV), before the coloring work is begun : —

1. Grass land (78).
2. Cleared land (79, 72).
3. Cultivated land (80).
4. Sand, gravel, and mud (81, 82, 52). Show an area of gravel in the upper left-hand corner, and one of mud in the lower right-hand corner. The color for sand should be blended with the ground color for the mud.
5. Individual deciduous trees (83). Arrange in rows $\frac{1}{2}$ inch apart, and space $\frac{1}{2}$ inch in the rows. The first row is to be $\frac{5}{8}$ inch from the top of the rectangle, and the first tree in each row $\frac{1}{2}$ inch from the left-hand edge.
6. Deciduous trees in mass (84).
7. Evergreen trees in mass (84).
8. Fresh marsh (85).
9. Salt marsh (86).

103. Exercise in Conventional Tints and Symbols (continued). The sheet is to be divided as for the last exercise.

1. Water, blue water lines (87, 57).
2. Water, flat-tint method (87).
3. Water, graded-tint method (87).
4. Embankment (90).
5. Cut (90).

6. Rocky surface (91).
7. Fence, walls, and hedge (92), drawn horizontally across the rectangle.
8. Streets and roads (88, 58), and railways (89, 59).
9. Buildings (93, 63) of wood, brick, and stone. Draw two of each, of different shapes, and arrange the whole in two horizontal lines.

104. Application of Conventional Tints and Symbols. As an exercise in bringing the tints and symbols together in a map the student may use the outlines of Plate II, or may invent a similar map for himself. An actual survey may also furnish excellent outlines, and be of special interest beside ; but it is seldom that an actual survey of so small an area as is desirable for this exercise will give opportunity for the use of all the conventional tints and symbols.

CHAPTER VI

SURFACE FORMS AND EARTHWORK

SECTION I. SURFACE FORMS

105. Representation of Surface Forms. In many engineering operations it is necessary to gain exact knowledge of the conformation of the surface of the ground. First of all, a survey is necessary to establish the relative heights of as many points on the ground as the problem in hand may require. As a common starting point from which to measure such heights, a level plane is chosen, in general lower than the lowest point on the ground whose height is to be determined. Such a plane is called a **datum**, and is usually taken at average mean tide in localities where the sea is accessible; in other localities an arbitrary datum is assumed. It is customary to speak of the relative height of a point as its *elevation*. Thus if a point is marked "El. 173.6," the meaning is that it is 173.6 feet above the datum which is used for that survey. If there be any doubt or misunderstanding as to what the datum is, the drawing should contain a note of explanation.

In sub-surface work, such as waterworks, sewer or dock construction, many points lie below the datum, and their relative heights are given with the minus sign prefixed; thus "El. $-$ 15.13" means that the point is 15.13 feet *below* the datum. There is always danger that a minus elevation will be mistaken for a plus elevation, and for this reason it is not un-

common, where much sub-surface work is to be done, to assume the datum 100 feet below that which is ordinarily used, so that no confusion may result, since all elevations will be positive.

When many elevations are recorded on a plan, and no doubt is possible as to the meaning, the figures alone are written, without even the abbreviation for "elevation."

The exact point whose elevation is recorded is marked by the decimal point in the number expressing the elevation, unless the point is plainly shown otherwise.

106. Representation by Recorded Elevations. The readiest means for representing surface form is by securing elevations of many points scattered over the area, and recording them, as described above, upon a plan of that area. It is then readily seen whether a given point in a region is higher or lower than one in another region. But the surface must be studied point by point, as the method does not present to the eye an idea of the surface as a whole; hence it is not generally used except for very limited areas, such as house lots.

107. Representation by Profile. When it is of interest to know the form of surface merely along a definite line, such as the center of a street or of a water pipe, the representation is usually made by means of a profile, which may be defined as the intersection of a vertical plane with the earth's surface or with other objects which are to be shown.

Fig. 46 shows, to a reduced scale, a profile drawn on "Plate A" paper (Art. 17). Note that the drawing would be of excessive height if it were carried down to show the datum, that is, down to El. 0.0. In such a case a line parallel to the datum, and at a convenient distance above it, is chosen from which to construct the profile. Such a line is called a **base line.**

The **stations** are marked along the base line. These are points at the extremities of 100-foot distances measured horizontally along the line on which the profile is taken. If the scale is large, as 40 feet to 1 inch, each station point is usually numbered; if the scale is small, only every fifth or tenth station need be marked. Any point between even stations is called a **plus**; thus a point at 530.6 feet beyond Sta. 0, the beginning of the profile, is called point 5 + 30.6, or its position is said to be at Sta. 5 + 30.6.

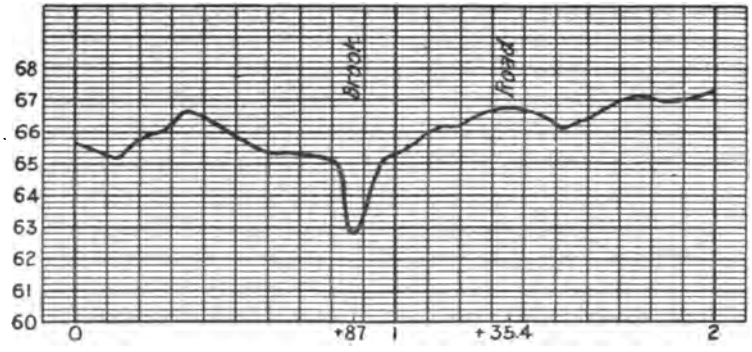


Fig. 46.

It is generally desirable that all irregularities and changes in direction of the surface lines of the ground shall be very marked. Consequently a different scale is used in laying off elevations above the base line from that used in laying off the stations, and profile paper is ruled to facilitate the making of such "**exaggerated**" **profiles.** If the surface is very irregular and precipitous, the same scale may be used for both horizontal and vertical distances, and such a representation is a "**natural**" **profile.**

The **scale of exaggeration** is the ratio of the number of feet shown horizontally per unit distance on the paper to the number of feet shown vertically to the same unit. Thus if the

horizontal scale is 40 feet to 1 inch, and the vertical scale is 4 feet to 1 inch, the scale of exaggeration is $40 \div 4 = 10$, which is the scale shown in the figure, and is very commonly used.

Since the rulings on profile paper are in color, and rather faint, the profile line itself stands out more clearly than is shown by Fig. 46, and the surface line is often accentuated by drawing a band of color immediately beneath it.

108. Cross-Sections. When a vertical section such as is described above is taken at right angles to the line of a profile, or across any well-defined longitudinal feature, such as a stream, cut, or embankment, the representation is called a cross-section. The lines shown in such a representation usually make well-marked angles with one another and no exaggeration is necessary. Therefore cross-section paper (Art. 17) has the vertical and horizontal rulings to the same scale.

109. Representation by Contour Lines. It is evident that none of the foregoing methods of showing surface form are suitable for giving even a general idea of the configuration of a considerable area. An adequate method must show at a glance the relative steepness of the surface along any line, and must also furnish means of obtaining readily and closely the distance horizontally and vertically from any one point to another, and the angle which any line in the surface makes with a horizontal plane — that is, the declivity of the surface along that line.

Such a method is found in the use of contour lines, which are drawn directly upon the plan of the area, forming a contour map, which is the basis for many designs and operations in engineering.

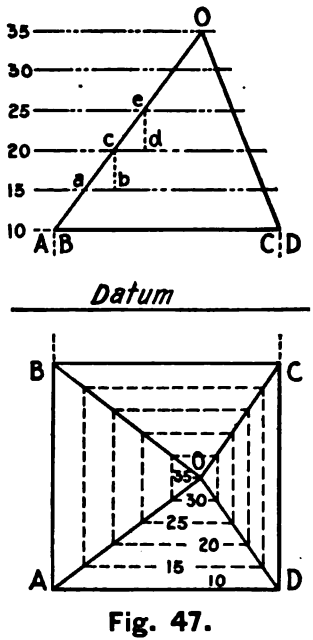


Fig. 47.

Fig. 47 shows a pyramid whose base is square and 10 feet above datum, and which is intersected by a series of horizontal planes parallel with the datum plane, and spaced 5 feet apart vertically. These planes intersect the surface of the pyramid in squares which are shown projected into the plan. If, now, there be written upon each of these intersections in plan the number (called the **reference number**, or simply **reference**) which shows its height above the datum, the information concerning the size and form of the figure is complete on the plan alone; for the shape and size of the base and the position of the apex show the general form of the figure and its dimensions in plan, while the intersections of the cutting planes, with their references, indicate clearly the height of the figure and the nature of the sloping surfaces.

This last statement may need further explanation. By studying the elevation and plan together the several facts will become evident. But for convenience let it first be stated that what have been called "intersections of the cutting planes with the surface" are **contours**, and a **definition of a contour** may be established as *the intersection of a level plane with the surface of the earth or other object through which it may be supposed to pass.*

For further convenience let it be stated that contours are given the names of their reference numbers; thus "contour 25" means the contour whose reference number indicates that it is 25 feet above datum.

The figure shows that the face COD makes a greater angle with the horizontal base than does the face AOB; that is, it is steeper. This is shown in the plan by the fact that the contours are closer together between O and CD than between O and AB. Hence *the closer together the contours in the same plan, the steeper the surface.*

But it is often desirable to know definitely how steep a surface is. The line *cb* is a portion of the projecting line of contour 20, and is therefore vertical, and *abc* is a right triangle in which *cb* is the vertical distance between contours 15 and 20, and *ab* is the horizontal distance between the same contours as shown in plan. But $\frac{cb}{ab}$ = tan of *cab*, which is the "angle of greatest declivity" of the surface between contours. Hence *the tangent of the angle expressing the steepness of the surface is the ratio,* $\frac{\text{vertical distance between contours}}{\text{horizontal distance between contours}}$. In general the horizontal distance must be scaled from the plan, while the vertical distance is the difference between the references of the adjacent contours.

By a comparison of triangles *abc* and *cde* it can be shown that $ab = cd$, and that therefore the corresponding contours are equidistant. In the same way it can be demonstrated that equidistance exists among all the contours on this surface, as shown in plan. Therefore *if a series of contours are straight and equidistant, the surface in which they lie is a plane surface.*

The student will readily discover the forms of contours which express other regular surfaces, and so be prepared to interpret the contours which express the irregular surfaces of the ground.

110. Interpolation of Contours. The information as to the topography of the ground is furnished by the surveyor in different forms, according to various circumstances. By some

field methods the contours are drawn directly on the "field sheets" used by the surveyor, or notes are furnished by which the contours are plotted by the draftsman without intermediate processes such as those described below ; but in general, economy dictates that a rapid method of survey be adopted, and this means that the notes furnished will not enable the draftsman to draw the contours directly, but will inform him as to the location of points of known elevation, either regularly spaced, as in Fig. 48, or scattered more or less at random. The **interpolation of contours** is the process of drawing the contours among these points from their established elevations.

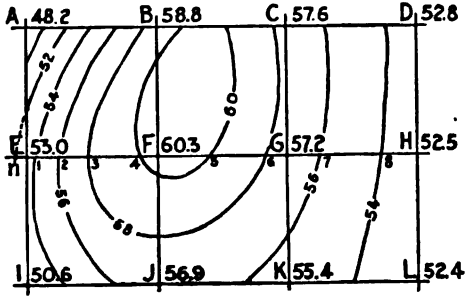


Fig. 48.

111. **Interpolation from Corners of Rectangles.** In some cases the ground is divided into rectangles or squares, and elevations are taken at the corners, as shown in Fig. 48. When the observed elevations are thus regularly spaced, the contours may be interpolated rapidly by means of the diagram shown in Fig. 49, which relates particularly to line EH of Fig. 48. EE, FF, etc. are vertical lines whose distances apart are equal to EF, FG, etc. of Fig. 48. Across these vertical lines are drawn horizontal lines spaced to some scale to represent the desired vertical distances between the contours, in this case 2 feet, as shown by the numbers 48, 50 . . . 62.

On EE is laid off the elevation of point E, Fig. 48, viz. 53.0. On FF is laid off the elevation of point F, and so on for points G and H. Through the points thus established a smooth free-hand curve is drawn as shown.

The horizontal lines 48, 50, etc., are spaced by a larger scale than is used to lay off the distances EF, FG, etc., hence the curved line above mentioned is an *exaggerated profile* along the line EH, and cuts the various level lines in points 1, 2, 3, etc., which are contour points whose distances from EE are the respective distances from E along EH, Fig. 48, at which the contours 54, 56, 58, and 60 cross EH.

Similar profiles are made for lines AD and IL, and the contour points having the same references are suitably joined and numbered, thus obtaining the finished contour map.

To copy the points 1, 2, 3, etc., of Fig. 49 in their proper positions in Fig. 48 the following method is advisable: Place the edge of a piece of paper along the line 54 and on it mark the position of EE, and points 1 and 8; shift the paper vertically to line 56 and mark the position of points 2 and 7. By further shifting the paper secure the positions of points 3 and 6, 4 and 5. Now lay this **tick strip** with its edge along EH, Fig. 48, with the point which marks the position of line EE placed at E. With a pencil mark the positions of 1, 2 . . . 8 on EH. But instead of marking them 1, 2, 3, etc., use the reference numbers of the contours to which they belong.

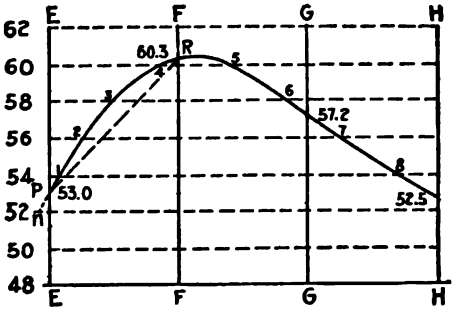


Fig. 49.

There will be an occasional contour which will not be fully located by the above operation, as contour 52, Fig. 48, in which case one or both of two things may be done. A profile may be constructed from the elevations at A, E, and I, which will give a point of the 52 contour on line AE; or the profile, Fig. 49, may be continued, as shown in dotted line, beyond EE to an intersection

with the 52 level at *n*, and the distance from *n* to line EE is then laid off from E on FE extended, Fig. 48, thus giving point *n*, toward which contour 52 is drawn.

In practice the diagram, Fig. 49, should be drawn on profile paper. The vertical lines should be inked, so that when one profile has been drawn in pencil and its results transferred to the contour map, it may be erased, leaving intact the necessary lines of the diagram for another profile. Indeed, several profiles may usually be drawn overlapping each other, before undue confusion arises.

It must be remembered that, in general, the corners of squares are not points at which there are sudden changes in the surface; instead, they are points on a smoothly curved surface, and the profile must be so smoothly drawn that if the points should be erased afterward, the line would not indicate the places where they had been. The profile may pass above the highest and below the lowest of the points. A rather soft pencil should be used, and the line sketched alternately in both directions till a smooth, continuous result is reached.

112. Interpolation on the Assumption of Straight Grades. It is often assumed that the surface line is straight between adjacent corners of rectangles, in which case the curved profile of Fig. 49 would be replaced by three straight lines, one of which, PR, is shown. This would give very different positions for the contour points from those obtained from the curved line which represents the more probable form of the ground.

When the ground is not rugged, and especially when the points whose elevation have been determined are scattered without order over the plan, the assumption of straight grades from point to point is usually made in interpolating the contours. Many methods for making the interpolations have been devised, but the principle involved is that of similar right triangles.

For instance, suppose two points, A and B, to be at elevations 18.3 and 29.6 respectively, and that they are 300 feet apart horizontally; also that even-numbered contours 2 feet apart are to be interpolated. The vertical distance between A and B is 11.3 feet, and the vertical distance from A to the first contour point, viz. 20, is 1.7 feet. If x be the required distance in plan from A to contour point 20, we shall have the following equation: $x = 1.7 \times \frac{300}{11.3}$. In the same way the distance from A to the last contour point, viz. 28, is $x' = 9.7 \times \frac{300}{11.3}$. The intermediate contour points would now be inserted by any convenient method so as to make four equal spaces from 20 to 28.

113. Summary of Principles regarding Contours. The first seven of the following principles depend upon geometrical conditions, the remainder upon engineering practice.

1. All points in the same contour line are at the same elevation.
2. Equally distant contours show uniformly sloping ground, and when they are also straight they show that the ground is a plane surface.
3. Contours do not cross each other. When they run together, they indicate a vertical surface.

An exception to the first statement might be shown in the case of a combination of hillside and overhanging ledge, but in practice the contours are run together at the ledge as if its face were vertical.

4. Every contour closes upon itself or disappears at the borders of the drawing, except that if it reaches a stream, practice dictates that it shall not be shown between the shore lines.
5. Contours are normal to lines of greatest declivity and to ridge and valley lines.

6. No single contour line lies between two higher or two lower ones, but two contours with the same reference may do so, indicating either a valley or a ridge.

A possible, though improbable, exception to the first statement is an instance in which a ridge or valley line is perfectly level and at exactly a contour elevation.

7. A contour map can be constructed from a sufficient number of profiles, and a profile on any line of such a map can be constructed from the contours and scaled distances.
8. The same equidistance should be used between contours in every part of the same map. If for a special reason it seems desirable to insert auxiliary contours, they should be shown dotted or in a color different from that used for the main system.
9. A break should be made in each contour (or more than one if the contour is long) for the insertion of the reference. If, however, the surface is very flat, so that contours are far apart, it is better to put the references on the high side of the contours.
10. For greater ease in reading a map a portion of the contours should be shown by heavy lines. For instance, if contours 2 feet apart are shown, all those whose references are divisible by 10 are drawn heavy.
11. The technical color for contour lines is burnt sienna, though black is often used if the map is to be blueprinted, photographed, or lithographed.

114. Determination of Slopes and their Intersections. In grading ground for pleasing effect, as in landscape architecture, rolling surfaces are almost wholly used. But in many engineering works it is necessary to use plane surfaces, and these are often made as steep as the nature of the soil will allow with safety. Such slopes are called formal slopes, and the steepness is expressed by the ratio of the horizontal base to the height. Thus a 2 to 1 (or 2 : 1)

slope is of such steepness that if its line of greatest declivity be taken as the hypotenuse of a right triangle, the base will be twice the altitude. This ratio is the cotangent of the slope angle, hence a 2 : 1 slope is found to be at $26\frac{1}{2}°$ with the horizontal, a $1\frac{1}{2}$: 1 slope at about $33\frac{1}{3}°$, etc. To show a 2 : 1 slope, for instance, by means of contours it is only necessary to draw the latter straight, parallel, and twice as far apart to scale as the vertical distance assumed between them.

Fig. 50 shows an embankment whose top is 20 feet wide, and level transversely, while it rises to the right 6 feet in each 100 feet of length measured horizontally. This is equivalent to saying that its slope is 1 : $16\frac{2}{3}$; but the longitudinal slope, or grade, of roads, etc., is

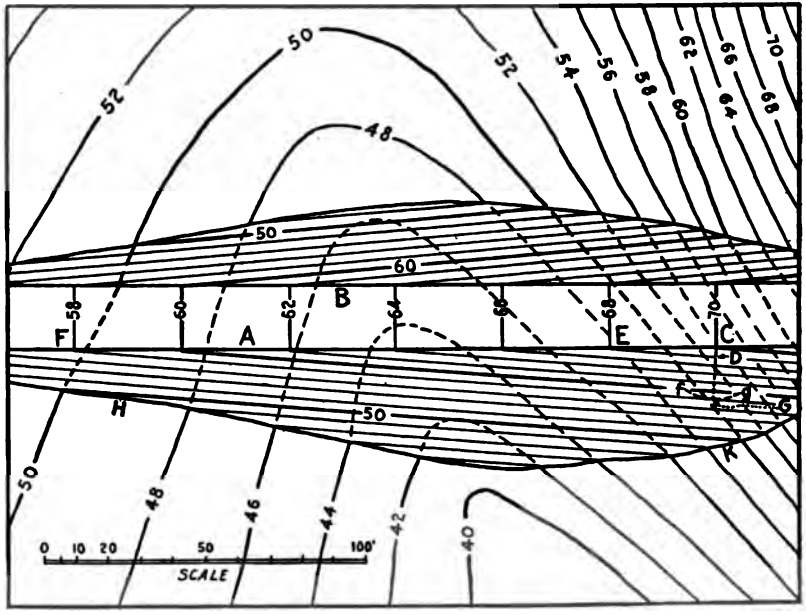


Fig. 50.

usually given in per cent; thus we should say that the top of this embankment has a 6 per cent grade. The side slopes are $1\frac{1}{2} : 1$, and the natural surface on which the embankment is constructed is as shown by the contours which are drawn full outside the embankment and dotted beneath it.

In constructing such a figure we should have the natural contours to start with. Then having determined the starting point, direction, and top width of the embankment, the side lines A and B of the top may be drawn. The contours 68, 70, etc., are next drawn across the top at the proper intervals to express the required per cent of grade. The intersection of these contours with the side lines of the top are points in the contours which express the side slopes, and whose direction must next be determined. From C the shortest distance to the next lower contour is $1\frac{1}{2} \times 2 = 3$ feet, while from C to E is $33\frac{1}{3}$ feet. Triangle CDE is therefore right-angled at D, and $\frac{3}{33\frac{1}{3}} = \sin CED$, from which the direction of ED, which is a portion of a required contour, may be determined.

A graphical method of determining the direction of the side-slope contours is generally preferable. From C as a center, and an opening in the dividers equal to several spaces between contours, as six, strike an arc *fg*. Then from F, which is the sixth contour point back from C at the top of the slope, draw FG tangent to *fg*. Triangle CGF is similar to CDE, but is taken large for greater accuracy.

The side-slope contours are now drawn and numbered. Those which do not start from the top of the slope are at first drawn of indefinite length in pencil. The definite length of any one of these is determined by the point or points in which it intersects a natural contour of the same number. Such an intersection is also a point on the toe of the slope, and the irregular line HK joining all such intersections is the toe of the slope, which must not be

confounded with a contour line, for it is the line of intersection between the natural surface and the formal side slope of the embankment.

Contours of formal slopes may be ruled, but for other surfaces, even though quite regular, they should be drawn free-hand.

Section II. Earthwork

115. General Statement. A very large item in many engineering operations results from the removal of earth in the construction of foundations, railway cuts, reservoirs, sewerage and waterworks, etc., and from the placing of earth in new positions, as in the building of roads, earth dams, railway and reservoir embankments, and in the grading of areas.

Payment for earthwork is usually by the number of cubic yards handled, hence the importance of methods by which volumes of earth, often of irregular form, may be determined.

The following are some of the methods in common use. The method to be adopted in any case will depend upon the general form of the volume, and sometimes upon the degree of accuracy desired.

116. Method by Four-sided Prisms. When an area of approximately rectangular form is to be excavated or filled, it may be divided into squares or rectangles of 20 to 100 feet on a side, and the volume of cut or fill within each square or rectangle treated as a four-sided prism. The elevations at the corners are obtained before work is commenced, and again after it is finished; the difference at any corner is the height of an edge of a prism, the area of whose right section is that of the square or rectangle laid out on the surface.

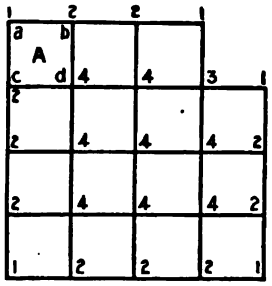


Fig. 51.

Suppose the area, Fig. 51, to be divided into squares as shown, that excavation be made over the whole area, and that the depth of excavation be determined at each corner, as, a, b, c, d. Then if A be the area of the square in square feet, the volume of excavation in cubic yards is

$$V = \frac{A}{27} \times \frac{a + b + c + d}{4}.$$

Each square might be treated in this way and the results added for total volume, but the work may be shortened by the use of an equation which provides at once for the fact that many of the corners are common to two or more squares, as shown by the figures written at the intersections. This is

$$V = \frac{A}{4 \times 27} (\Sigma h_1 + 2\Sigma h_2 + 3\Sigma h_3 + 4\Sigma h_4),$$

in which A is the area of one square, Σ is the symbol for "sum of," and h_1, h_2, etc., are corner heights, the subscripts indicating the number of times each is taken because of its being common to 1, 2, 3, or 4 squares.

117. Method by Three-sided Prisms. The method last stated assumes that the bases of the prisms are plane surfaces, whereas the upper bases, at least, are likely to be otherwise.

It is always possible to pass a plane through three given points. If a diagonal be drawn to each square of Fig. 51, we shall have the volume divided into triangular prisms, and it is safer than in the case of square prisms, to assume that their bases are planes. After the ground is staked out each square should be examined to determine which of its two diagonals should be chosen so that the upper bases of the resulting triangular prisms shall lie as nearly

as possible in a plane. Fig. 52 shows that corner heights may be common to triangular prisms varying in number from one to eight.

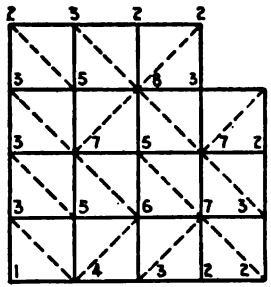


Fig. 52.

If A still be the area of a square in square feet, the equation for total volume in cubic yards is

$$V = \frac{A}{6 \times 27} (\Sigma h_1 + 2\Sigma h_2 + 3\Sigma h_3 \ldots \Sigma h_8).$$

118. The Prismoidal Method. In Fig. 53 is shown a prismoid, which is a solid having parallel bases, and which may be composed of any combination of prisms, cylinders, pyramids, cones, wedges, or their frustums, whose bases and apices lie in the bases of the solid. But since the cylinder and cone are particular forms of the prism and pyramid respectively, and since frustums may be resolved into the simpler solids, the following is a sufficient **definition: The prismoid** is a solid having parallel bases, and may be composed of any combination of prisms, pyramids, and wedges, whose bases and apices lie in the bases of the solid. If a volume-equation can be found which is common to these three solids, it will be applicable to their combination as described.

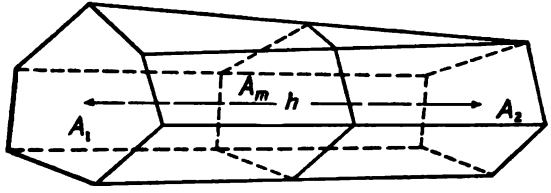


Fig. 53.

In Fig. 53 let A_1 and A_2 be the areas of the bases of the prismoid, and h the perpendicular distance between them. Also let A be the area of a right section midway between the bases. Then

$$V = \frac{h}{6} (A_1 + 4A_m + A_2),$$

which is the **prismoidal formula**, for it may be shown that it applies to each of the elementary solids of which the prismoid may be composed.* This formula is rigidly correct for all true prismoids. The only approximation made in its application to earthwork is in assuming that the sides of the figure are either plane or warped surfaces, while the natural ground surface may be quite otherwise ; but by taking h sufficiently small the figures may always be made to approach closely to true prismoids.

If the ground is very uneven, care should be taken to choose the positions of the bases of the prismoids so that the apices of elementary pyramids and the edges of elementary wedges will lie in the end bases of prismoids and not between them ; otherwise the figures will not closely approximate true prismoids.

It should be carefully noted that the area of the middle base, A_m, is not an average of the areas of the end bases, but that the lengths of its sides are averages of the lengths of the corresponding sides of the end bases. This must be kept in mind when, as is sometimes necessary, the value of A_m must be found by interpolating between the known values of A_1 and A_2.

119. Consecutive Prismoids. In railway cuts and embankments, canals, cuts and fills for roads, etc., the work is usually cross-sectioned at regular intervals, as 25, 50, or 100 feet, thus making a series of prismoids end to end, the value of h being twice the distance between sections. By reference to Fig. 53 it will be seen that if this were the first of a series of prismoids, A_1 would be used once, while A_2 would be used twice (since it is the end of the figure shown and the beginning of the next in succession), while A_m belongs only to the prismoid

* This formula gives also the volume of the sphere and of the regular solids of revolution.

shown. Instead, therefore, of computing each prismoid separately and adding results, an expression for the whole series may be written,

$$V = \frac{h}{6 \times 27} (A_1 + 4 A_2 + 2 A_3 + 4 A_4 + 2 A_5 + \ldots A_n).*$$

If the elementary volumes be odd in number, the above equation will not include the last one, which must be computed separately, either by interpolating A_m, as described in the last article, and treating it as a prismoid, or by one of the methods of Art. 121.

120. Application of Prismoidal Method to Grading. The prismoidal method may be applied to advantage to most of the problems that arise as to quantities of earthwork. Suppose a hill to be leveled or a depression to be filled; then the areas included within contour lines may be made the bases of prismoids, and twice the contour interval will be the height.

121. Methods Approximating the Prismoidal Method. For the sake of simpler calculations one of two assumptions is sometimes made in calculating the volume of the prismoid, viz.

1. $V = \frac{h}{27} \times \frac{A_1 + A_2}{2}$,* which is called the method of average end areas.

2. $V = \frac{h\, A_m}{27}$,* which is called the method of mean areas.

If the figure is a true prism, it is evident that neither of these equations involves any approximation; but in the case of a prismoid the first equation gives results too large, the second one gives results too small, and the error in the first assumption is twice as great as that in the second.

* Twenty-seven is here placed in the denominator to give the volume in cubic yards.

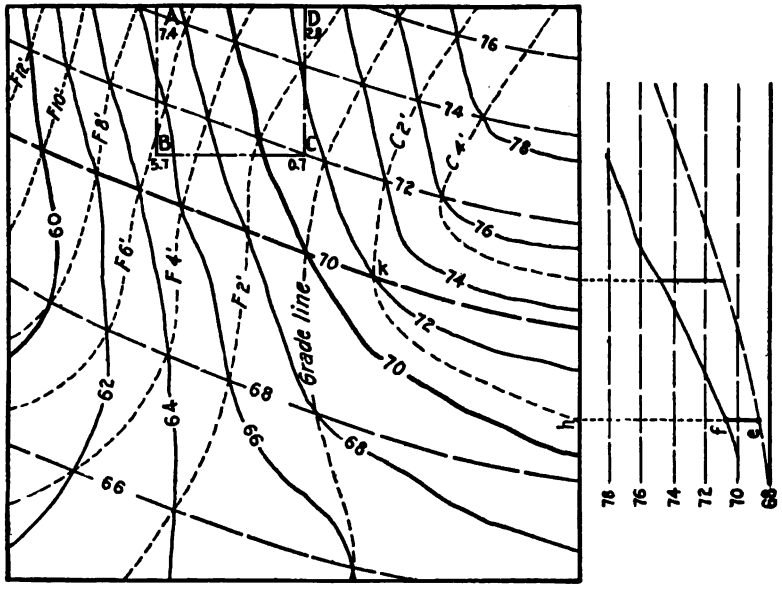


Fig. 54.

The following may be taken as a general guide in the selection of the method: —

1. If the end areas are nearly alike, the method of average end areas may be used.
2. If the end areas differ considerably, the method of mean areas or the prismoidal method should be used.
3. If the end areas differ greatly, only the prismoidal method should be used.

122. Volume from a Contour Map. In Fig. 54 are shown three series of lines which, if the student is not skilled in reading contour lines, must be very carefully studied, one series at a time, till the surface forms which they express are clearly in mind.

The full lines are the "natural" contours, showing the natural or unimproved ground surface. Note that those whose references are divisible by 10 are heavy lines to aid the eye

in carrying the form as a whole. The lines in long dashes are contours showing what the surface will be when graded. Both systems are to be regarded as based upon the same datum.

At a point nearly in the middle of the figure, contour 70 of the first system crosses contour 70 of the second system. At this point therefore the ground will be neither cut down nor filled up by the proposed grading, and it is called a "grade point." Just above this point is one where the 72 contours of both systems cross, and this is another grade point. There are four other similar points, and the dotted line joining them is a "grade line." It should be noted carefully that this is not a contour line, for its lower end is at an elevation 10 feet below that of its upper end. It is simply a line along which the proposed grading will not necessitate either filling or cutting, but is common to both the present surface and the proposed new surface. Another way of stating the case is that if we were to construct two profiles upon this line, first using the natural contours, and then using the proposed contours, the two profiles would be identical.

At the left of the point to which attention was first called above is a point where the 68 contour of the natural system is crossed by the 70 contour of the proposed system, which means that at this point the ground is to be made two feet higher than it is at present; or as it is commonly expressed, there is to be a 2-foot fill. There are four other points at which the intersecting contours denote a 2-foot fill, and a dotted line is drawn through them all and marked F2′. This line is of the same nature as the grade line; it is not a contour, but is simply a line at all points of which there is to be a fill of two feet.

In the same way are constructed other lines showing successively increasing fills up to 12 feet.

At the right of the grade line there are also intersections of contours of the two systems,

but in each instance it is a contour of the original system which has the greater reference, showing that the ground is to be cut away instead of being filled up. By tracing out these intersections the lines for 2-foot cut and 4-foot cut were drawn.

Referring to the line of 2-foot cut, it will be seen that there are four points at the upper part of the figure to determine it, leaving it at *k* with little indication as to its further course. The next point which we should look for would be formed by the crossing of contour 70 of the natural system and 68 of the proposed system. But these do not cross within the limits of the drawing. They could be continued by guess to an intersection beyond the limits, and thus furnish a point toward which to draw the dotted line from *k*. But such a point would be at too great a distance from *k* for accurately determining the position of the dotted line within the limits of the figure. It would help, however, to the conclusion that the dotted line runs out of the figure at its right-hand side, and between contours 70 and 72 of the natural system.

The auxiliary figure at the right shows a method by which a point on the 2-foot-cut line may be located at the boundary of the figure. This shows, in full line, a profile of the natural surface, and in broken line a profile of the proposed surface, each taken along the right-hand boundary of the main figure, and for convenience projected directly from the points where the several contour lines reach it. Then by trial the place is found where these profiles are two feet apart, vertically, to the scale used in constructing the profiles. This point is at *ef* in the figure, and is shown projected to *h*, which is the desired point to which to draw the line of 2-foot cut. Any other point in this line between *h* and *k* may be found by constructing similar profiles on a base passing through the desired location of the point. Such a base might be parallel to the boundary of the figure, but would more naturally be taken so as to be about normal to the contour lines which it would cross.

The volume of cut and fill may now be estimated by either one of the three following methods: —

1. With a planimeter measure the area bounded by the grade line, the F2′ line, and the top and bottom limits of the figure. Multiply this area by 1, which is the average fill in feet over the area. Measure the area bounded by F2′, F4′, and the limits of the figure, and multiply it by 3, which is the average fill over this area. Proceed in the same way with all the similar areas which are in fill, and add the results for the total volume of fill in cubic feet. Obtain the volume of cut in the same way.

In many cases areas will be of irregular shapes, and it will be evident, for instance, that more than half of a given area is subject to a fill greater than the average of the fill at its edges. In such a case judgment must be used as to the exact quantity by which the area is to be multiplied.

2. With a planimeter determine the area included by the grade line and the limits of the figure at its left. Measure also the similar areas determined by lines F2′ and F4′ respectively. These three areas may now be taken as the three bases of a prismoid whose height is the united heights of the two layers of fill thus involved; that is, in this case, four feet. Other successive prismoids may be formed in the same way, both for the remaining fill and for the cuts.

3. The entire area may be divided into squares or rectangles, each of which will be the base of an elementary prism of cut or fill. One square of such a series is shown at ABCD. By inspecting the position of its corners with reference to the adjacent fill lines, the depth of fill at each corner (that is, the height of each edge of the prism) may be rather closely estimated, and the volume may be found as explained in Art. 116.

It is evident that some prisms will be partly in fill and partly in cut. In this case the algebraic sum of corner heights may be taken, or the prism may be divided into two irregular ones at the grade line, and each taken separately.

In practice a set of contours such as the proposed contours of Fig. 54 may not disappear at the limits of the drawing, where they would seem to be conveniently disposed of. If there are summits or depressions without outlets, some of the contours will close upon themselves; otherwise they must ultimately run into and be merged with the natural contours of the same reference numbers, since no grading operations are of unlimited extent.

123. Treatment of the Plan. The systems of lines shown in Fig. 54 may be brought out in various ways according to the exact purposes of the plan, and with reference to the degree of skill possessed by those who will examine it.

The natural contours may be shown in full lines, either black or burnt sienna, while the proposed contours may be broken lines in black or full lines in some color. The lines of cuts and fills may be dotted lines in black or full lines in still another color. If the plan is to be examined by one unskilled in reading such drawings, it is best to use colors rather freely.

If the plan is to serve as a construction plan for work already decided upon, the new contours are best drawn in full lines, while the natural ones are dotted, and the lines of cuts and fills, if shown at all, in some color.

A very good plan, when much work is to be done upon such an area, is to make one tracing showing the natural, and another showing the proposed, contours. The two tracings may then be used separately to obtain prints; or, by superposing one exactly upon the other, a print

may be made showing both sets of contours, which may then be used for calculations of volume, for comparison of the two surfaces, etc.

It is sometimes of interest to use different tints to distinguish the areas in cut from those in fill; or one of these areas may be cross hatched for the same purpose.

124. Balancing Cuts and Fills. If excavation is in excess of fill, the surplus earth must be deposited in a **spoil bank**, often at a distance from the work; if the fill exceeds the cut, material must be obtained from a **borrow pit**, which involves expense both for material and transportation.

It is therefore desirable, whenever possible, to design the work so that the material excavated will be sufficient to make the fills; also that the cuts and the equivalent fills be not far separated, for if surplus earth has to be carried more than a certain distance (often stipulated as 500 feet in contract work), an extra charge is made for the **overhaul**. The balancing of cuts and fills, as it is called, is done on the profile for such work as highway and railroad construction, where the area covered is long and narrow. The surface usually may be assumed as approximately level transversely to the profile, so that if the proposed new surface line be kept above the profile of the natural surface in some places by about the same amount that it passes below it in others, the volumes in cut and fill will approximately balance.*

A trial surface line is usually found by holding a thread taut and placing it in various positions on the profile until one is found that satisfies the eye as to equivalence of cuts and fills. This position is then drawn in pencil and the volumes calculated.

* The cuts must be somewhat in excess of fills to allow for the fact that earth shrinks when deposited in embankment.

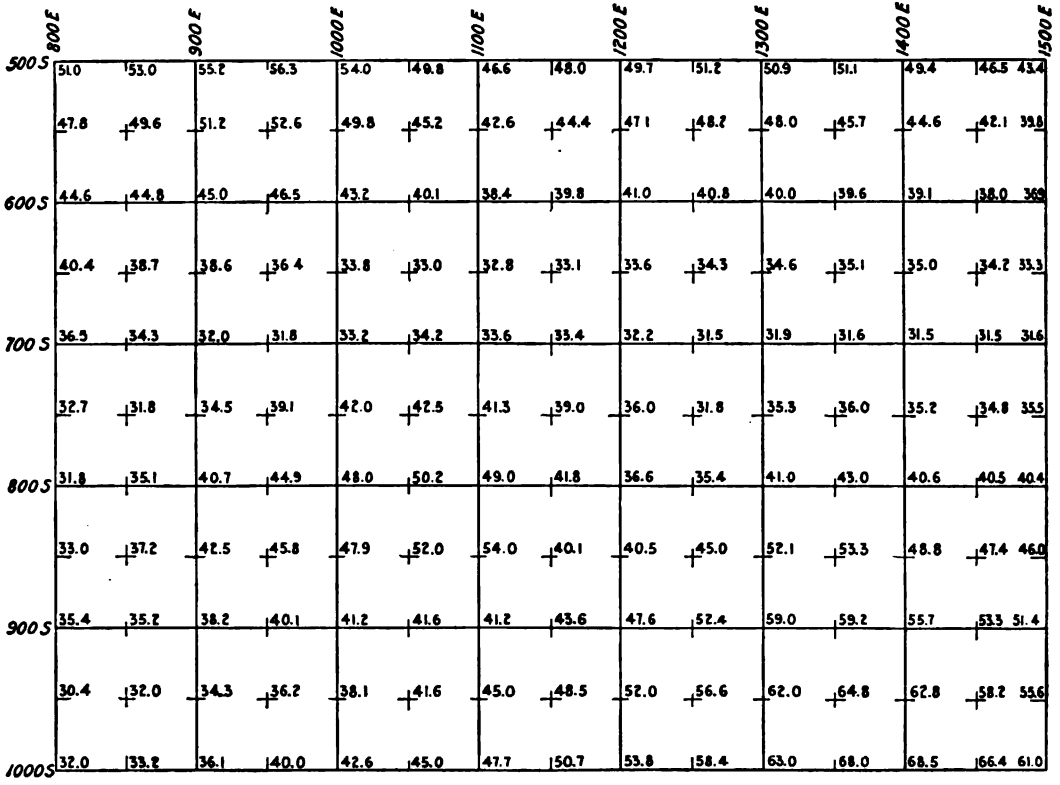
In grading over an extended area a contour plan such as that shown in Fig. 54 is the best means for studying the cuts and fills. Starting with the natural contours, a trial set of new contours may be sketched on rather roughly. Then it will be seen by inspection whether the cuts and fills approximately balance. In the figure it is evident that the fill is largely in excess of the cut, not only because the area covered by it is greater, but also because the required depth is greater. A nearer approach to a balance may be made by simply renumbering the proposed contours. If, for instance, each be marked two units less, the grade line will be thrown to the position now occupied by F2′, thus making the area in cut somewhat greater than that in fill; moreover, the greatest fill will be reduced to 10 feet, while the greatest cut will be increased to 6 feet. If a slightly greater cut and a slightly smaller fill be found desirable, then some or all of the proposed contours will be moved toward the top of the figure.

125. Problems. The contour map whose construction is required in Problem 1 is the basis for the subsequent problems. Problems 2, 3, and 4 may be worked out on one sheet without overlapping, and the same is true of Problems 5 and 6. Problem 7 requires a whole sheet.

The most satisfactory way of solving the problems is to work each group on a sheet of tracing cloth fastened over the contour map. It will then be easy to omit parts of original contours covered up or cut out by the structures under consideration.

1. To a scale of 1 inch = 50 feet draw coördinate lines 800 E. to 1500 E., each inclusive, and 500 S. to 1000 S., each inclusive, as shown on Plate V. These should be inked and numbered at once in red, the lines being made very fine. Draw in pencil an intermediate set of coördinates, thus dividing the whole area into 50-foot squares. The corner heights are not

Plate V.


800 E
900 E
1000 E
1100 E
1200 E
1300 E
1400 E
1500 E
500 S
600 S
700 S
800 S
900 S
1000 S
51.0 53.0 55.2 56.3 54.0 49.8 46.6 48.0 49.7 51.2 50.9 51.1 49.4 46.5 43.4
47.8 49.6 51.2 52.6 49.8 45.2 42.6 44.4 47.1 48.2 48.0 45.7 44.6 42.1 39.8
44.6 44.8 45.0 46.5 43.2 40.1 38.4 39.8 41.0 40.8 40.0 39.6 39.1 38.0 36.9
40.4 38.7 38.6 36.4 33.8 33.0 32.8 33.1 33.6 34.3 34.6 35.1 35.0 34.2 33.3
36.5 34.3 32.0 31.8 33.2 34.2 33.6 33.4 32.2 31.5 31.9 31.6 31.5 31.5 31.6
32.7 31.8 34.5 39.1 42.0 42.5 41.3 39.0 36.0 31.8 35.3 36.0 35.2 34.8 35.5
31.8 35.1 40.7 44.9 48.0 50.2 49.0 41.8 36.6 35.4 41.0 43.0 40.6 40.5 40.4
33.0 37.2 42.5 45.8 47.9 52.0 54.0 40.1 40.5 45.0 52.1 53.3 48.8 47.4 46.0
35.4 35.2 38.2 40.1 41.2 41.6 41.2 43.6 47.6 52.4 59.0 59.2 55.7 53.3 51.4
30.4 32.0 34.3 36.2 38.1 41.6 45.0 48.5 52.0 56.6 62.0 64.8 62.8 58.2 55.6
32.0 33.2 36.1 40.0 42.6 45.0 47.7 50.7 53.8 58.4 63.0 68.0 68.5 66.4 61.0

to be copied on the drawing, but used directly from the plate, and the intermediate coördinate lines are to be erased as soon as the contours are drawn.

By the use of the corner elevations construct profiles on the *north and south lines* (the reason will appear when the contours are drawn), and from these, as explained in Art. 111, find contour points from which 2-foot contour lines are to be drawn.* The profiles should be made on profile paper. A vertical scale of 1 inch = 8 feet is suitable. Show the contours and their references in B.S., and use a heavy line for each contour whose reference is divisible by ten.

2. On line 900 E. as a center line, a cut extending the entire width of the map is to be made under the following requirements: bottom width 25 feet; elevation of bottom 30.0; side slopes $1\frac{1}{2} : 1$. On a scale of 1 inch = 10 feet draw cross-sections at every 50 feet along the center line, showing the original surface and the required cut. From the planimetered areas of the cross-sections find the volume of the cut by the prismoidal formula. By the use of the proper points taken from the cross-sections, draw on the map, in full black lines, the intersections between the side slopes and the natural surface. Draw the foot of each slope in black, and rule the contours on the slopes in B.S., but do not draw any of the latter till the top of the slope has been drawn as above described.

3. The rectangle bounded by 500 S., 1000 S., 1200 E., and 1500 E., is to be graded to a plane surface described as follows: at point 1000 S., 1200 E., its elevation is to be 38.0; it is to be level along all lines running northeast and southwest; and it is to have a grade of 3%

* The teacher may find it advisable, as a means of saving time, to distribute the making of the several profiles among members of the class, and then to allow an exchange of tick strips. A further division of labor may be made by allowing some students to read elevations while others plot them. But each student should interpret for himself the contour points obtained.

running downward to the northwest. Draw 2-foot contours in black to express this surface, the natural contours being in B.S. Draw grade lines in dotted black, lines of fill in blue, and lines of cut in red. Find the volumes of cut and fill, (*a*) by the prismoidal method, (*b*) by method (1) of Art. 122.

4. The strip between lines 1000 E. and 1100 E. is to be graded to a surface conforming to the following description: beginning at 1000 S. it is to slope upward toward the north 3 % for the first 200 feet; thence 100 feet level; thence for 100 feet 4 % downward; thence for 100 feet 6 % upward. Express these surfaces by 2-foot contours in B.S., so placed that the cuts will approximately balance the fills. Divide the area by blue lines into squares of 50 feet on each side, and calculate the quantities of cuts and fills by method (3) of Art. 122. (Suggestion: construct a profile of the natural surface along the center line of the strip, and, on tracing paper or cloth, construct also the profile of the required surface without regard to actual elevations. Lay the second profile over the first, and in such relation to it that a balance of cuts and fills seems to be secured. The positions and references of contours to express the required surface may now be determined.)

5. The square bounded by lines 500 S., 800 S., 800 E., and 1100 E., is a borrow pit. Successive layers of earth are taken out, the surface of the excavated area being left level in each case. These layers extend respectively to elevations 52, 44, 36, and 28. The sides of the excavation are on a slope of $1\frac{1}{2}$ to 1, and the tops of the slopes follow the boundary of the square. Find the volume of each of the four layers. (Each of the three upper layers is in two parts, but is called one layer.) Use black lines to show the upper layer, blue for the second, red for the third, and green for the bottom. Colored lines may be drawn close to contours when these form parts of boundaries.

This is the kind of problem on which much time may be spent in applying a refinement of method for computing quantities. When the conditions do not lend themselves readily to the application of a theoretically exact method, it is often better to apply *with judgment* an approximate formula to large volumes rather than to cut such volumes up into smaller ones which may be computed by the prismoidal formula, for instance. In the present case it will be noted that portions of layers are of uniform thickness, but of unequal top and bottom areas; while other portions are of unequal thickness as well. It is suggested that each layer or independent section of a layer be divided into two parts, for one of which an average base shall be chosen, and for the other both a proper base and thickness shall be chosen for computing volumes.

6. The center line of a highway starts at point 1000 S., 1200 E., and runs due north 200 feet, where it turns to the right by an arc of 100 feet radius, and continues due northeast to the edge of the map. The roadway is to be 50 feet wide, and for simplicity is to be considered level transversely. At the point of beginning its elevation is 50.0. It has a downward slope of 4% to the beginning of the curve, from which point it is level. The side slopes are 2 : 1 for both cut and fill. By means of 2-foot contours alone work out the lines showing the tops and toes of the slopes. Calculate the length of the roadway (measured horizontally) on its center line, and, calling the point of beginning Sta. 0+0, write the stations on the center line, including the pluses at the end of the curve and at the upper border of the map. Draw the center line and the tops and toes of slopes in black, but use B.S. for slope contours.

7. A rectangular reservoir has a flat, level top 25 feet wide and at El. 48.0. The outside corners are at points 600 S., 900 E.; 600 S., 1400 E.; 900 S., 900 E.; and 900 S., 1400 E. The outside slopes are 3:1, and the inside slopes are 1:1. The bottom is flat, and at El. 6.0. By

means of contours only find the tops and toes of all slopes. Compute the volumes of cuts and fills by such method or methods as seem best adapted. Ink in blue the contours relating to fills, and in red those relating to cuts, using black where coutour lines are also the tops or toes of slopes. Use 2-foot contours for the outside slopes, and 6-foot contours for the inside slopes.

CHAPTER VII

CONVENTIONAL TREATMENT FOR SURFACES AND SECTIONS

126. Reasons for Treatment. The present chapter has reference to the treatment of materials employed in building structures which rest directly upon the earth, and also of the natural earths, rock, and water. It is outside the scope of this work to speak of the conventional treatment of metals and some other materials of engineering.

A drawing may serve its purpose if it shows only outlines of figures and divisions between different materials. But if proper and suggestive conventional treatment or "rendering" be used to indicate different materials, especially on sections, the drawing is much more easily read, and is therefore more useful, as well as more attractive, and hence more satisfactory. By the use of appropriate conventional signs it is possible to avoid many notes on the drawing which otherwise would be required to explain the nature of, and the relations between, the various materials. Again, the use of conventions enables the engineer to express shades of quality of construction work; for instance, in uncoursed rubble, the quality of work as to the fitting of stones may be expressed rather more clearly than in written specifications.

127. Materials in Elevation, Plate VI. The term *rendering* is applied to the treatment of materials in elevation or plan to indicate the nature of the materials, or the form of the objects, or both. The nature of materials is brought out by more or less suggestive conventions, and forms are expressed by shades and shadows.

The conventional treatment for the most commonly used materials is as described below, and shown on the plate.

1. **Hammered-face Stone.** After the joints are drawn pencil lines are ruled parallel with and near the left-hand and upper edge of each stone, and the spaces between these and the joints are left blank to give relief to the work, and to suggest the "draft" which is often cut around the face. The sets of short vertical lines are then drawn with a fine pen. Regularity of order among these sets of lines is to be avoided. Fine dots are then added to fill up the larger blank spaces and to clearly define the draft lines. By using very fine lines and dots a delicacy of treatment may be given which it is not easy to show in an engraved plate.

2. **Rock-face Stone.** The edges of the stones of this class are usually "pitched" to a straight line. This line is suggested by leaving a narrow blank area at the top and left-hand of each stone. The bottom and right-hand edge of each stone is then finished in a heavy and quite irregular shadow line. Next are drawn the heavy shadow lines on the faces of the stones to define the edges of projecting portions. Areas of medium dark tone are next shown by sets of parallel lines, and a few dots are added last of all. Considerable practice may be found necessary to avoid an unpleasing monotony in showing this face. It will be found very helpful to study an existing rock-face wall, making pencil sketches of individual stones.

3. **Split-face Stone.** The rendering consists simply of groups of vertical lines. Some variety should be sought in the grouping of these, and the upper and left-hand edges of the stones should be avoided.

4. **Uncoursed Rubble.** The outlining of individual stones should have reference to the sizes of stones, the allowable thickness of joints, and the allowable departure of bed joints from a horizontal line. If spalls are to be used to fill the larger joint spaces they are to be outlined,

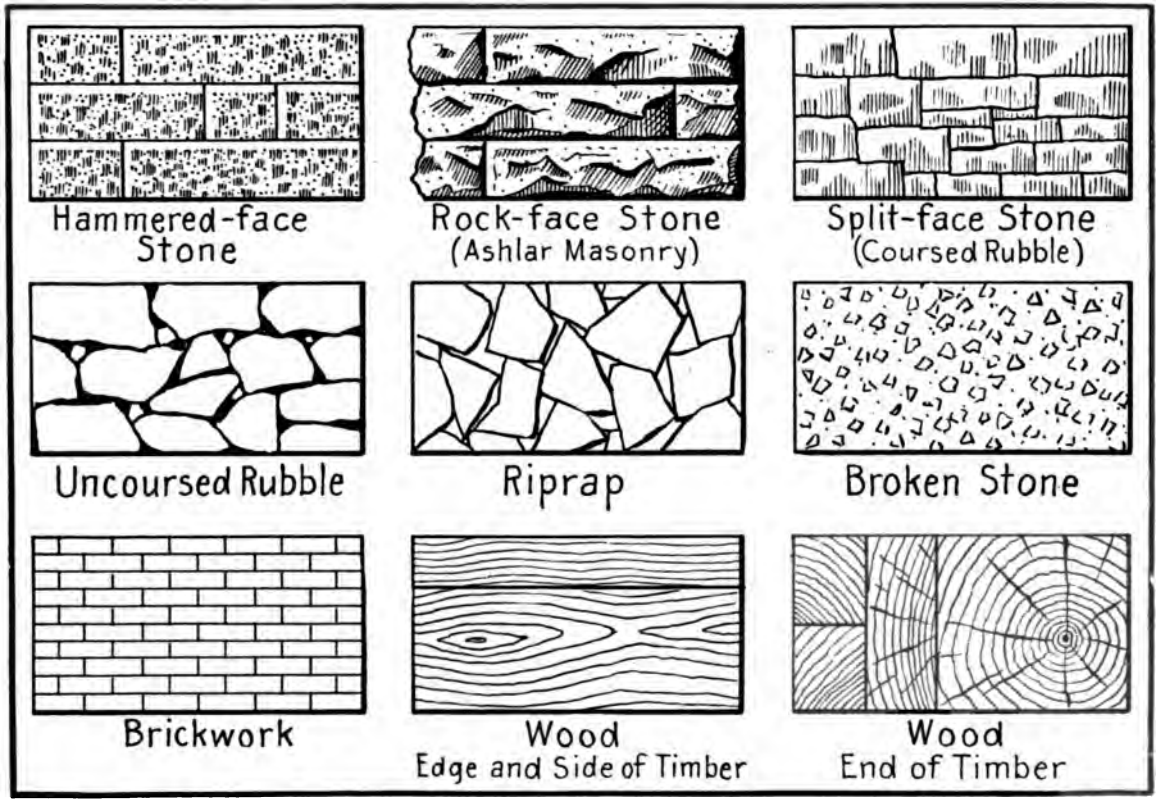


Plate VI.

UNIV. OF MICH.

and the remaining portions of the joints are then to be made solid black. If it is desirable to distinguish between dry rubble and rubble laid in mortar, the solid black joints may be used for the dry work, while dots placed thickly in the joint spaces may indicate mortar.

5. **Riprap.** The drawing should show the sizes of stones allowed by the specifications, and should also indicate the quality of work as to the relative positions of stones. If the stones are to be dumped in place, the drawing should show them placed without regularity; if they are to be placed by hand, some regularity of arrangement should be shown, as in uncoursed rubble.

6. **Broken Stone.** Sketchy and rather widely separated suggestions of irregular pieces of stone, with a few dots in the larger open spaces, form this convention. The lower and right-hand edges of the stones should be drawn with a little heavier pen stroke than is given to the other edges. It will usually be necessary to draw individual stones much larger than they would actually be to the scale of the drawing.

7. **Brickwork** is shown by simply indicating the joints. In order that the treatment be suggestive the individual bricks must be drawn to scale, and this becomes very laborious when the scale of the drawing is small. Hence it is not uncommon to use no convention at all for brickwork, the outlines only of the structure being shown. It is often quite sufficient, and even preferable, to show the convention on portions only of the whole area of brickwork. The limits and character of the work can thus be shown with comparatively little labor.

8. **Wood.** There are two characteristics common to most kinds of timber, which suggest the methods of showing it on drawings. First, all woods grow by the addition of yearly layers extending around the trunk. There are visible lines separating these layers, and they are

called annular rings. These furnish the concentric curves by which the end of the timber is most suggestively shown. Secondly, many trees, notably the oaks, have thin plates of close-grained material called medullary rays arranged radially, and therefore cutting the annular rings normally. When a log is cut into timber, the saw-cut intersects the rings and rays in ever-changing lines and figures. To indicate the characteristics of the different varieties of wood by showing the figures furnished by the medullary rays would involve too much labor, and it is customary to consider only the lines furnished by the rings, except that in showing the end of timber the rays are drawn. The edge of timber (and especially of boards and planks) is shown by somewhat wavy lines not joining each other, and not closing upon themselves, while the side is shown with more variety of marking. Observation of the lines on unfinished timber will be useful in giving hints as to variety of markings.

128. Materials in Section, Plate VII. The nature of materials is universally indicated on cross-sections of structures, and very commonly on profiles.

In several cases the conventions on this plate contain section lining, and directions are given as to the spacing of the lines. Thus for brickwork the spacing is "2 at 42°." This assumes that the Both section liner (Art. 10) will be used, in which case the pawl is to be arranged to pass two notches on the bar, and the ruling arm is to be set at 42° on the arc. The whole instrument should then be turned so that the ruling arm will be at 45° with the lower border of the drawing. In the plate all section lines are shown running upward to the right. In practice, however, if there are adjacent areas to be cross-sectioned, the alternate ones should have the lines running upward to the left, whether or not the material in the adjacent areas is the same.

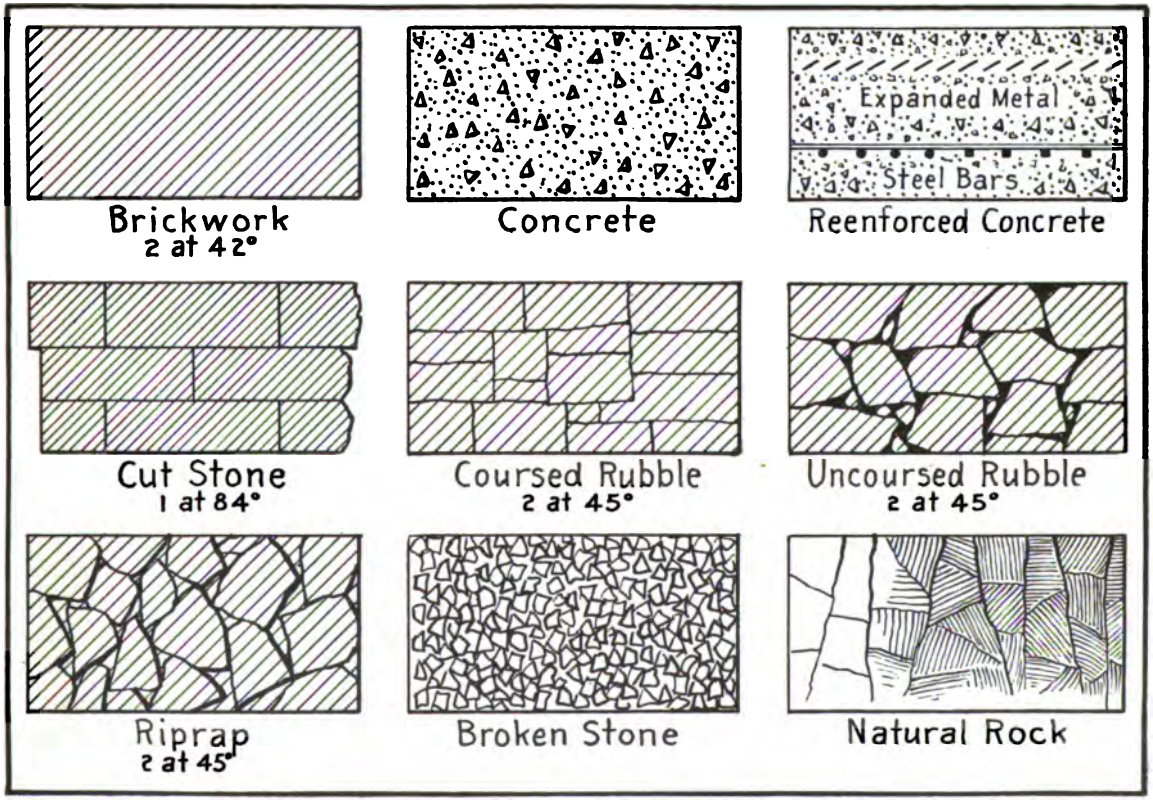

Brickwork
2 at 42°
Concrete
Expanded Metal
Steel Bars
Reenforced Concrete
Cut Stone
1 at 84°
Coursed Rubble
2 at 45°
Uncoursed Rubble
2 at 45°
Riprap
2 at 45°
Broken Stone
Natural Rock

Plate VII.

The spacings given are suitable for moderately large areas and ordinary working scales. If the areas to be section-lined are very small, the lines should be drawn closer together.

1. **Brickwork** is shown by simple lining as indicated. If the scale is large, the joint lines between individual bricks may also be shown.

2. **Concrete.** The area is first covered with triangular markings to represent broken stone, the right-hand and lower sides being shaded, and care being taken that the bases of the triangles are not all parallel, but rather arranged in a variety of positions. The remainder of the surface is then covered with dots to represent sand and cement.

3. **Reënforced Concrete.** The concrete itself is represented as described above, except that near the reënforcement the triangles are made small and sketchy.

Expanded metal is shown by short lines drawn at 30° with the horizontal, the lower end of each line being slightly to the right of a vertical through the upper end of the preceding line.

Steel bars are shown in elevation or section as the case may require, and may be either round or square, according to the choice of bar.

4. **Cut Stone.** In general the joints in a cross-section will not be as close as shown in the figure except for a short distance back of the face. The whole is section-lined as shown.

5. **Coursed Rubble.** The arrangement of joints is to be made in accordance with the quality of work contemplated, and the surface section-lined as shown.

6. **Uncoursed Rubble** is like the same work in elevation with the addition of the section lines.

7. **Riprap** is shown as in elevation except that section lines are added.

8. **Broken Stone.** Individual stones are fully outlined and placed close together. To

avoid placing them in rows it is well first to cover the area with stones placed far apart, and then gradually fill up the spaces with other stones.

9. **Natural Rock.** First draw the long lines which are nearly vertical, and slightly crooked and tapering. Then draw the second set of lines between these, and finally the sets of fine parallel lines having a variety of directions.

129. Materials in Section (continued), Plate VIII.

1. **Natural Earth.** First work across the top of the area, putting in the sets of short parallel lines extending, for instance, downward to the left. Then go over the same ground again, putting in the sets extending downward to the right, and finally the horizontal lines. In the same way treat another narrow strip below the first, and so continue till as much space is treated as is desired, gradually making the lines finer and farther apart.

2. **Earth Filling.** It is best to start with sets of lines having a certain direction, and to scatter the groups widely over the area. Then draw scattering groups having another direction, and thus gradually cover the area, being careful that wide spaces to be filled with dots are left between adjacent groups. Variety should be sought in making lines of varying length and number in the groups, and by making some lines slightly more crooked than others.

3. **Filling in Layers.** Draw first the long, broken, and moderately heavy lines whose distances apart are to express the thickness of the layers. Then follow with the closed figures representing gravel, the short fine dashes, and finally the dots.

4. **Clay** is expressed by lines of short dashes at 45° with the horizontal. In starting the lines care should be taken that the first dashes in the various lines shall not be of the same length, also that variety be made in the length of the dashes in each line, otherwise many breaks between

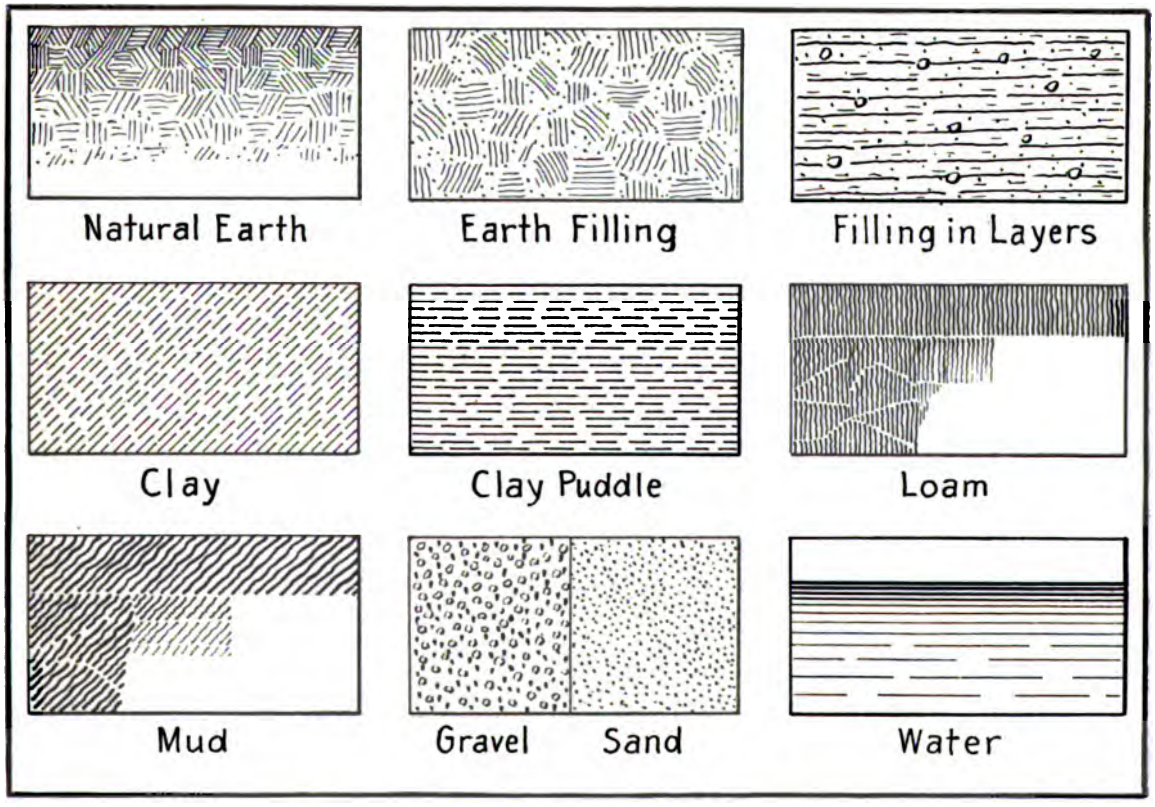

Natural Earth
Earth Filling
Filling in Layers
Clay
Clay Puddle
Loam
Mud
Gravel
Sand
Water

Plate VIII.

dashes in successive lines will come opposite one another, giving an undesirable appearance of white lines crossing the area.

5. **Clay Puddle.** This is like the above, except that the lines of dashes are horizontal. The same caution must be observed concerning rows of breaks between dashes.

6. **Loam.** Loam is most commonly deposited as a layer above other filling. In this case, and also when a natural layer is to be indicated, the depth of the layer is defined in pencil, to scale, and the space is then filled with rather heavy vertical lines with spaces between only slightly greater than the thickness of the lines. The latter should be slightly wavy, and the undulations in one line should correspond in position with those in the preceding line.

Occasionally loam is deposited in a mass rather than in a layer, in which case other series of lines are drawn below the first. The ends of these, however, need not define a horizontal line, but may define diagonal and curved lines as shown at the left of the figure; then if the ends of lines in adjacent groups are not brought quite together, there will be an appearance of irregular white lines running through the area.

If it is desired to show an indefinite depth, the lines are tapered downward as shown at the middle of the figure.

7. **Mud.** This convention is the same as that for loam except that the lines are heavier, farther apart, and drawn at 45° with the horizontal.

8. **Gravel** is shown by first covering the area with small closed figures approximately circular in form, and shaded on the lower right-hand side; these represent the larger stones, and should be distributed at random. The smaller stones and sand are represented by dots evenly distributed among the closed figures.

Sand is shown by dots evenly distributed and placed at random so as not to suggest ar-

rangement in lines. The sizes of the dots may be varied to indicate different degrees of fineness of the sand. This should be done by using coarser or finer pens, and not by differing pressures on the pen. In order to make the dots rapidly, and yet keep them dots, rather than short dashes or tapered strokes, the following precautions should be observed: hold the pen at a large angle with the paper — about 65°; move the pen vertically up and down so as to strike the paper squarely; touch the paper so lightly that the nibs of the pen will not be spread.

9. **Water.** The surface is shown by a heavy line, and as the work proceeds downward the lines are made lighter and farther apart. The last few lines are broken at intervals to assist the appearance of gradually fading away. Blue ink may be used with good effect, but should be employed only on drawings that are not to be blueprinted or photographed for reproduction.

10. **Wood.** The same conventions are used for wood in section as were described in the last article, and shown in Plate VI for wood in elevation.

130. Geological Profiles and Sections. The nature and depths of soil and earth are determined by means of test pits, "wash borings," or by steel sounding rods, while diamond drills are used for exploring rocky substrata. If such information be obtained at points rather close together and along suitable lines, geological profiles or sections of a fair degree of accuracy may be constructed.

Plate IX shows two such sections. In the upper one are shown the outlines of the structure which is to be erected along the line where the section is taken. Note the different spacing of the lines denoting clay. "Soft blue clay" is properly shown by lines spaced wide apart as

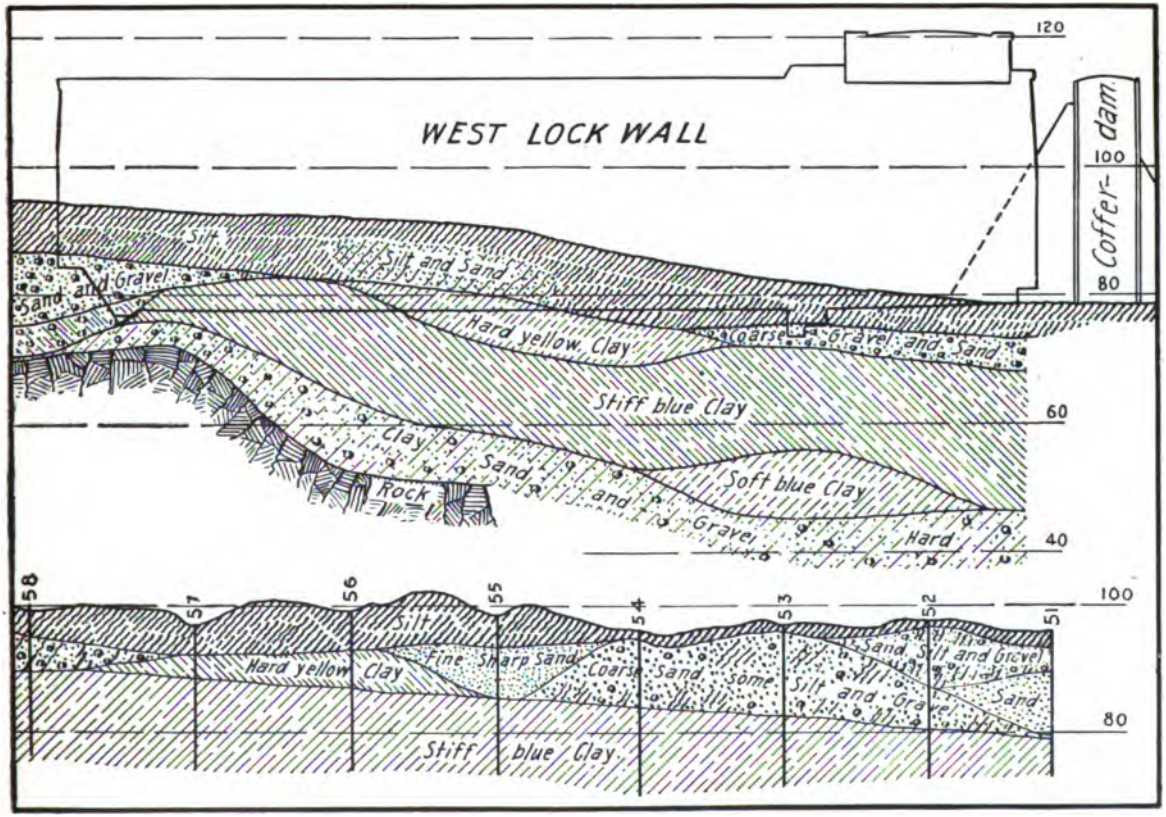

WEST LOCK WALL
120
100
80
60
40
Coffer-dam
Silt
Sand and Gravel
Silt and Sand
Hard yellow Clay
Coarse Gravel and Sand
Stiff blue Clay
Clay
Sand and Gravel
Rock
Soft blue Clay
Hard
58
57
56
55
54
53
52
51
Silt
Hard yellow Clay
Fine Sharp Sand
Coarse Sand
Some Silt and Gravel
Sand
Silt and Gravel
Sand
Stiff blue Clay
100
80

Plate IX.

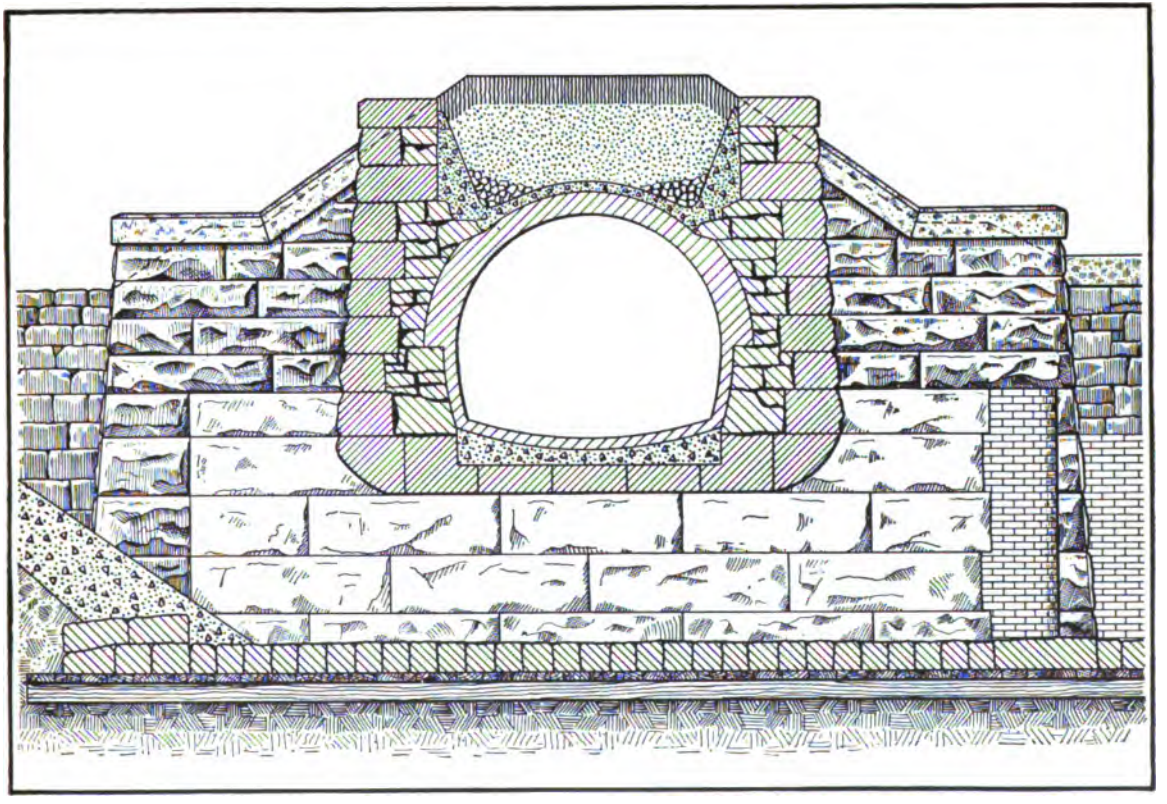


Plate X.

compared with those showing "stiff blue clay," while those in the stratum marked "clay, sand, and gravel, hard," are still farther apart to allow room for the symbols for sand and gravel. The alternation of direction of lines in the several strata also helps to make plain their lines of separation.

In the lower section the heavy vertical lines and the numbers at their upper ends show the positions, depths, and numbers of the borings from which the section was built up.

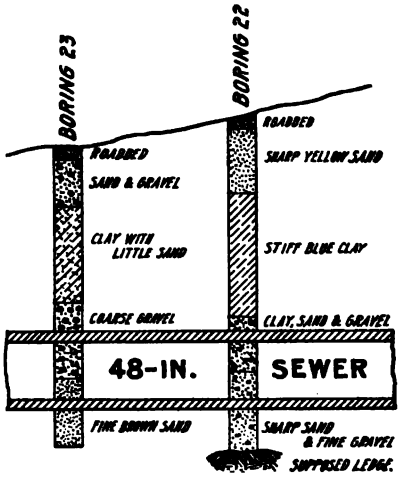


Fig. 55.

131. Borings. It is not always easy to build up a geological section from borings. Rather than attempt to show complete strata from evidence which may be capable of more than one interpretation, it is customary to show, especially on contract drawings, the indications furnished by the borings, allowing those who are interested in the matter to interpret for themselves. Fig. 55 exhibits the method of showing borings on profiles. The center of each boring is at the proper station, but the diameter is much exaggerated so as to make room for the symbols; the vertical depths of the strata and of the whole boring are to the vertical scale of the profile.

132. Illustration of Cross-Sectioning and Rendering. Plate X shows a section of an aqueduct at a culvert which passes beneath. It illustrates the use of several of the conventions described above, in bringing out the different materials and showing their relations in the structure.

CHAPTER VIII

COPYING, REDUCTION, AND ENLARGEMENT OF PLANS

133. Copying by Blueprinting. The most common method of merely duplicating engineering drawings is by the process of blueprinting. The universal adoption of this method has caused a complete change in the manner in which nearly all sorts of plans are made. Whereas they were formerly made on thick paper, and frequently with the free use of colors, both in inks and in washes, they are now more simply made on thin, translucent tracing paper or cloth, the lines being generally in black only. The use of colored washes to express different materials in section has given place to the use of conventional combinations of lines, as described in the last chapter. All these changes are to secure drawings which may be blueprinted easily.

For making blueprints several articles are necessary: **the frame,** which is substantially like any photographic printing frame, having a clear glass front (plate glass if the frame is more than two feet long), and a removable back which is preferably in sections hinged together; a soft, thick **pad** of felt or woven stuff to introduce between the back and glass; a **tray** or shallow tank for washing the prints; and the sensitized **blueprint paper.**

The tracing to be reproduced is first placed in the frame with its face against the glass. A piece of the sensitized paper somewhat larger than the tracing is then placed with its prepared face against the back of the tracing, the pad is placed over both, and the back is secured

in place by means of wooden bars which carry springs bearing with some force against the back, so that the paper and the tracing are held in close contact. The whole is then exposed to the sun, which, shining through the glass and the tracing, produces chemical changes in the coating of the paper so that it becomes an insoluble Prussian blue, which appears as such, and is fixed against further change by washing the print in clean water. But the opaque lines of the drawing on the tracing prevent the chemical rays of the sunlight from reaching the paper immediately beneath them, so that when the print is immersed in water, the coating of the paper at these points is washed away, leaving the original white of the paper. Thus the ordinary blueprint shows lines, letters, and figures, the color of the original paper on a blue background. The print will be more permanent if allowed to remain in the bath for 15 or 20 minutes before being hung up to dry.

The time of exposure to the sun varies greatly with different papers. Some will print in 30 seconds in bright sunlight. It is often a great convenience to use so "quick" a paper, but the prints are likely not to be as permanent as those made from paper requiring an exposure of at least one minute.

There is a great difference also in the amount of overexposure, or "burning," which different papers will stand, and still yield fairly good prints. In all cases a burned print must be soaked for a long time (say an hour) to bring out the best result.

134. The Sensitizing Solution consists essentially of red prussiate of potash and ammonium ferric citrate, one part of each in 25 or 30 parts of water. This must be kept away from sunlight, and is applied with a sponge in a dark or dimly lighted room. A thin coating is sufficient, but it must be evenly applied. The best paper has a smooth hard surface. The

prepared paper is sold so cheaply by dealers, and in such variety of weight and texture, that it is seldom desirable for the draftsman to prepare it for himself.

135. Making Corrections on Blueprints. Lines which are to be eliminated may be gone over carefully with water color mixed to match the color of the background. A quicker method is to apply an eraser to the lines until the blue background in the immediate vicinity has been so nearly rubbed off that the lines are much dimmed. The area is then gone over with a blue pencil and a stump till the intensity of color of the background is matched.

Lines may be added to a print with Chinese white, but a better result is obtained by the use of a strong solution of sodium carbonate, which will bleach the blue of the background, thus allowing the natural color of the paper to show through. The solution should be used in a new writing pen; and if used with a right-line pen, the work should be done quickly, and the pen should be thoroughly cleaned at once, as the solution has a corrosive action.

If additions are intended to be prominent, red or yellow ink or water color may be added to the sodium solution. The blue will still be bleached, allowing the color to stand upon a white background, and so be much more brilliant than if applied as color only to the print. If, however, scarlet vermilion or Dutch chrome be mixed very thick and applied to the print, the effect is good.

136. The Printing Value of Colors. If colors, either in the form of pencils, inks, or water colors, are used on a tracing, it is usually of some importance to consider what effect these will have upon prints; for the kind of color as well as its density is a factor in its printing quality. Broadly speaking, red and yellow print well, while blue does not. Green prints fairly well if the yellow in it is in excess of the blue, as does also

purple if the red is in preponderance. Orange, which is a combination of red and yellow, prints very well. Scarlet vermilion, if mixed thick, prints as well as black. Blue is often used on tracings to bring out water surfaces, but it must be put on very heavily if its effect is to be secured in prints.

137. Printing from a Thick Drawing. Prints may be made from drawings made on Whatman's or other opaque drawing paper, and even on Bristol board, by first saturating the drawing with benzine applied with a cloth. This renders the paper translucent for the time being, but does not expand it, and does not affect the ink.

138. Copying by Means of Vandyke Negatives. Vandyke paper, like blueprint paper, is sensitized for printing from a tracing by sunlight or by electric arc light. The resulting prints show white lines on a Vandyke-brown background. These prints are not easy to read, but if such a one be used for printing instead of the original tracing, brown lines on a white ground will be secured if Vandyke paper is used, or blue lines on a white ground will result if ordinary blueprint paper is used. The first print, showing white on brown, is called a negative, for in making it the tracing is placed in the frame with its *back* to the glass, thus causing everything on the resulting print to read backward, as in a photographic negative. When the negative is used instead of the tracing for making prints, it is placed in its turn with its back to the glass, and the final prints are thus made to read direct. The object of these reversals of the usual order is to avoid bringing the thickness, first of the tracing, and secondly of the negative, between the lines of the drawing and the sensitized face of the paper; otherwise the light would be slightly diffused before doing its work, and the printed lines would not be so clean-cut.

The process of printing with Vandyke paper is exactly like that with blueprint paper except that in addition to the water bath the Vandyke paper is given a bath of "Vandyke salt" solution, which intensifies the brown color.

139. Making Corrections on Vandyke Negatives. The white lines may be stopped out on a negative by the use of any opaque water color or with India ink. An "erasing fluid" is sold by dealers which bleaches the brown color, and which may therefore be used to add white lines in the negative, or to strengthen dim lines.

140. Special Uses of Vandyke Negatives. The Vandyke process affords an opportunity, as does no other process, for combining parts of different drawings in one print, and of changing titles, notes, etc., on prints. Suppose, for instance, that the title of a drawing is to be changed. A negative of the drawing is made, and also one of the proposed new title. The old title is then cut from the negative of the drawing, the piece cut out being slightly smaller than the negative of the new title, which is then pasted over the opening, and the whole is ready for use. The only unusual condition is that there are two thicknesses of paper where the pasting is done; but if the negatives are dense, this fact will not be shown by the prints, and at the worst there will be only a band of slightly different color from the rest of the background.

In some cases original plans of land must be permanently given up, as when they are filed in county registries with deeds or similar instruments. These plans are usually tracings, copies of which it is desirable to keep. Vandyke negatives may be made from such tracings before they are filed, and from them prints may be made as needed.

141. Use of the Copying Glass. When a copy of a drawing is to be made on paper so opaque that the lines of the original cannot be seen through it, the copying glass (Art. 13) is a great convenience. The drawing is first laid upon the glass, and over this is placed the paper for the copy, the two being held in place by paper weights, or by thumb tacks if their edges extend beyond the glass. The lights from the lamps below will render the lines of the drawing plainly visible, and they may be simply traced upon the upper sheet.

142. Copying by Pricking. When no copying glass is at hand, the best means for reproducing a drawing on thick paper is by the method of pricking. The blank sheet is placed beneath the drawing to be copied, and the two are held together by weights or thumb tacks. A pricker (Art. 15) is then thrust through the salient points of the drawing into the sheet beneath. These points are the vertices of prominent angles, the centers of circular arcs, and points near each other on irregular lines. When all the necessary points are thus transferred, a few of the most important ones are identified on the lower sheet (a corner or side of the upper drawing being turned back to give access to the lower sheet), and joined by pencil lines. A few such lines will serve to identify points after the upper sheet is entirely removed, and by joining them with pencil lines in proper order the whole drawing is rapidly built up. If the drawing is quite simple, the points may be joined at once by ink lines.

143. Copying with Transfer Paper. If a drawing is on thin paper, it may be copied by means of transfer paper. The ordinary carbon paper used by typewriters may be employed for this purpose, or a substitute may be made as described in Art. 17.

The drawing to be copied is laid face up upon the blank sheet, with the transfer paper between them, its prepared face being turned downward upon the blank sheet. A sharp but

smooth point (a hard pencil will do) is then passed with a little pressure over the lines of the drawing. The pressure will cause the sheet below to be blackened along the path of the moving point, or as is usually stated, the lines of the drawing are transferred to the under sheet.

144. Copying, Enlarging, and Reducing by the Pantograph. The pantograph was described in Art. 12. This instrument is not frequently found in engineers' offices because a really good one is expensive, and because it takes up considerable room. It is of great advantage in reducing and enlarging drawings because it works rapidly, reproduces directly (although in pencil), and, when the arms are properly set, allows no chance for errors except such as arise from a poorly made instrument. Moreover, the original drawing and the reduced or enlarged copy may be on any kind of paper.

145. Reducing and Enlarging by Proportional Squares. By this method the drawing to be copied is first ruled into squares, as shown at (*a*), Fig. 56. For convenience the squares are lettered from left to right, and numbered from bottom to top. The rectangle which will contain the enlargement or reduction in the desired size is then drawn on a separate sheet, the ratio of width to length being the same as that of the width to length of the original. The rectangle is then divided into the same number of squares as are contained in the original, and the squares are lettered and numbered to correspond with the original, as shown at (*b*) in the figure.

If the sides of the squares are not of great length, and if extreme accuracy is not required, the salient points of the drawing may be located merely by inspection. For instance, point

G in (*a*), Fig. 56, is seen to be at about one third of the distance down from the top of square D – 4 and about one fourth of the distance from left to right. With these relative distances in mind the point G can be located with considerable accuracy in the corresponding position in square D – 4 of (*b*).

If greater accuracy is necessary, proportional dividers (Art. 6) may be used for locating the points from the sides of the squares. Some parts of a drawing may contain much more detail than others. In this case the squares covering the position of such details may be subdivided, and the work followed out as above described.

Curved lines are generally best located by noting the points where they cross the sides of squares. If, however, the curve is a circular arc whose center is in the drawing, the center is first carefully located and the curve is drawn with compasses set to the proper radius.

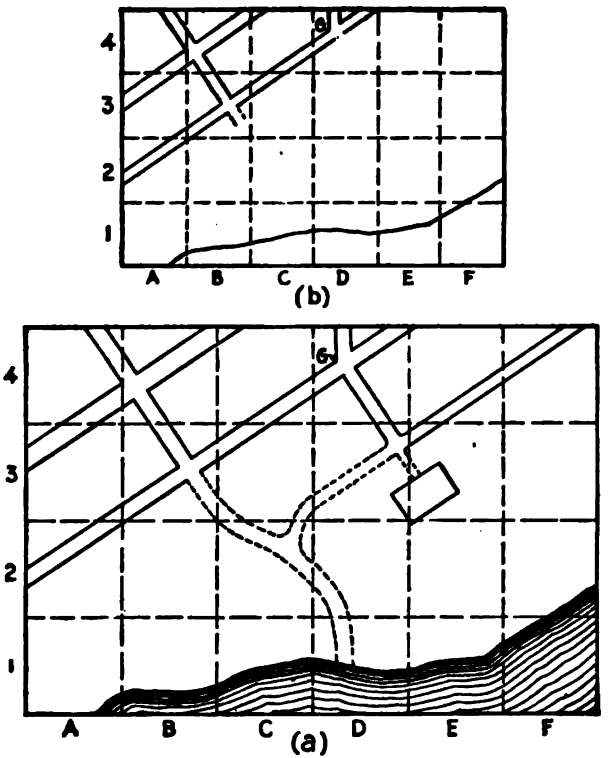


Fig. 56.

There may be objection to pencil lines even, on the drawing to be copied. In this case the squares may be defined on tracing cloth, which is then placed upon the drawing, thus in effect dividing the latter into squares. The cloth is sufficiently transparent so that the lines of the drawing show through, and the work of enlargement or reduction progresses as above described.

146. Photography, Lithography, and Photo-engraving. Drawings may be readily copied by photography. The copies are printed directly from the glass negatives, either the ordinary photographic papers or ordinary blueprint paper being used. Ordinarily the drawings are considerably reduced when reproduced by this method, and with a good lens the reduction can be made quite accurately to a required scale. Large negatives are expensive, and also awkward and bulky to preserve.

Lithography affords a most satisfactory means of reproducing drawings either to the same or to a reduced scale. The process is costly if only a few copies are required, but is not expensive if many are needed. This process is especially adapted to the production of large maps, as the stones from which they are printed are obtainable in large sizes.

Photo-engraved Plates usually furnish the readiest means of reproducing maps and drawings if the number desired is considerable, if the greatest dimension is not more than two feet, and if the work is not to be shown in colors.

In all the above-mentioned processes photography plays a part ; in photo-lithography the lines are transferred from the drawing to the stone by means of one or more photographic negatives, while in photo-engraving the drawing is transferred to a zinc plate by photography, the plate then being etched in a chemical bath. It follows that the original drawing must be